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A CONTRIBUTION TO THE MORPHOLOGY AND DEVELOPMENT OF THE MAMMALIAN LIVER.

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A CONTRIBUTION TO THE MORPHOLOGY AND DEVELOPMENT OF THE MAMMALIAN LIVER.

As is the case with all the organs of the body, the liver of man received much earlier and more detailed attention at the hands of the morphologist than did the corresponding organ of mammals in general. Thus the earliest accounts of the comparative anatomy of the liver were based upon its form and characters in the human subject. But it has come to be recognised that the human liver, in common with the majority of human organs, has undergone a high degree of specialisation during the process of evolution; with the result that it cannot be regarded as a type suitable for descriptive purposes, but must, rather, be istelf compared with more primitve and generalised forms.

It is now generally agreed that the so-called lobes of the human liver are arbitrary divisions of the organ made for convenience of description, and are not, correctly speaking, of comparative morphological value. In human anatomy, a striking misuse of the term "lobe" occurs in the expression "quadrate lobe". The "quadrate lobe" is merely a quadrilateral area on the visceral surface of the liver bounded on the left by the longitudinal fissure and on the right by the depression for the gall-bladder. It is not defined by true fissures; for the so-called longitudinal or unbilical "fissure", as will be shown later, is not the same in character or in origin as are the real fissures of the liver of mammals in general. Moreover, though too much importance must not be be attached to the relative size of any given area, it may, nevertheless, be pointed out that the "quadrate lobe" is not of constant dimensions even in the human subject; and its homologue in the Mammalia as a whole is of remarkable variability. Rolleston(1) has shown that, in man, it may be absolutely large, and as much as three times the size of the remainder of the under surface of the liver; whereas, on the other hand, it may be quite rudimentary even where no pathological lesion exists.

The right and left lobes of the human liver, as described, correspond to four lobes of the comparative anatomist. It has been shown beyond question that the differentiating fissures have disappeared; a series of livers from animals standing close to man in the zoological scale demonstrating the process of disappearance. Occasionally man reverts to a more primitive condition, and some or all the fissures reappear. Among examples of such reversion is one recorded by Parsons (2) where a human liver had two lobes to the right and two to the left.

The only parts of the liver of man which can be said to have retained their independence in any degree are the Spigelian and caudate lobes. Even these are no longer decided; though they may be well-marked and distinct, as has been shown by Thomson (3). As bearing on phylogeny, as well as on ontogeny, it is of interest to note that they are of proportionally greater size in the foetus than in the adult (cf. Thomson (4)).

In spite of several hypotheses by which it has been sought to explain the absence of lobes in man and other mammals, the question of the true factor or factors still affords ground for discussion. Duvernoy (5) was of opinion that the character of the

food

food, and the correlated conformation of the stomach, should be regarded as having a profound influence on the formation of fissures and lobes. Others have held a like opinion. As an illustration of the effect of a large and complicated stomach in the direction of reduction of hepatic fissures, the ruminants have been cited. Bemond question the ordinary ruminants have a compact liver; but, even in closely allied species with stomachs of relatively equal size, there is a certain measure of difference in the presence or absence and in the relative depth of fissures, and in the size of the lobes. The domestic ruminants, to seek no farther, while possessing the same gastric peculiarities, have livers readily distinguishable. Those aberrant ruminants, the camels, have a stomach no less complex than that of the more ordinary members of the same order, and yet there are two well developed fissures dividing the liver into three lobes (cf. Lesbre (6)).

In the horse the stomach is small, but its place is taken physiologically by the enormous large intestine. The hollow abdominal organs of the horse are hardly less ponderous than those of ruminants; still the liver has not been compacted, but has all the fissures associated with the typical mammalian organ.

Whatever influence the character of the alimentary canal may have on the liver of mammals in general, man and the anthropoid apes form a stumbling-block in the path of anyone wishful to enunciate an universal law. From man down through the anthropoids to the lower monkeys, all grades of lobation may be demonstrated. It is obvious, then, that some factor other than the conformation and disposition of the stomach and intestines must play a part

in

in the obliteration of fissures. Keith (7) has considered the position and mode of fixation of the liver as factors in its lobulation in Primates. He is of opinion that the erect posture has caused the disappearance of fissures in man and the anthropoid apes. As the result of the assumption of an upright position, the dorsal mesentery has acquired a more complicated mode of attachment consequent upon the removal of the support formerly afforded to the liver by the ventral abdominal wall. Correlated with the more extensive fixation of the liver to the dorsal abdominal wall is the disappearance of fissures This hypothesis, unfortunately, does not take cognisance of the fact that a practically undivided liver is met with outside the Primates, in mammals in which the position is prone and where the dorsal mesentery has undergone no complicated modification.

Keith also observes that, in the anthropoid apes, the abdomen, as well as the thorax, has been widened at the expense of the dorso-ventral diameter, and that this has had its effect upon the form of the liver. The difference in the shape of the thorax and abdomen of the anthropoids and the lower monkeys as a whole is undoubted; but the present writer (8) has pointed out that the predominance of the lateral over the dorso-ventral diameter is not confined to the anthropoid apes. It is also demonstrable in some, at least, of the Old World monkeys; and in these there has been practically no alteration of the liver from the more generalised mammalian type. But even more important in this connection is the fact that in some New World monkeys (e.g. Lagothrix humboldti) the dorso-ventral flattening of the trunk is decidedly pronounced without there having been any effect whatever on the hepatic fissures. In Humboldt's

woolly

woolly monkey the lobes are as distinct as, or possibly more distinct than, in Cercocebus fuliginosus - an Old World monkey with a trunk of somewhat the same relative diameters as in the average mammal.

Ruge (9) has also endeavoured to explain the differences in liver conformation as being due to modification in the form of the trunk, and to a flattening of the dome of the diaphragm. The same objections to this hypothesis might be adduced. In Lagothrix the diaphragm was found to be much flatter than in the sooty mangabey.

Rex (10), whose communication will be discussed in greater detail later, considers that the arrangement of the blood-vessels within the liver is to be regarded in association with the form of the organ as a whole; but he scarcely seeks to explain the absence or presence of fissures as being dependent upon vessels. Homologous regions of the liver in different animals may have homologous vessels whether fissures are present or not.

It is safest to conclude that no single hypothesis, as as yet propounded, consists with all the known facts relative to the shape of the mammalian liver, and the presence and depth of its fissures. No doubt the form and volume of the abdominal viscera, the habitual attitude of the animal, the relative dimensions and degree of mobility of the trunk, all play a part in producing a correlated moulding of the liver; but, so far as our present knowledge goes, it may be reasonably assumed that no single factor is sufficient to account for all the varied modifications met with in the examination of a series of organs derived from different mammalian orders.

Consequent

Consequent upon the lack of a recognised type with which the liver of different mammals might be compared, great confusion prevailed in the writings of descriptive anatomists at the beginning of last century. It is no easy task to make the description of one writer of that period fit in with the account of a contemporaneous, or nearly contemporaneous author. The works of Cuvier and Meckel may be cited as examples of classics illustrating the great want of uniformity in the treatment of the same subject.

In 1835, Duvernoy (5) expressed himself as dissatisfied with the method, or rather want of method, followed by the comparative anatomist of that day. The discord which prevailed in the number of lobes assigned to the liver in general works and in monographs, he describes as remarkable. The mammalian liver, he goes on to say, may be simple, or very complex. Between the two extremes there are a certain number of modifications of form easy of recognition and description if the method he has devised be adopted. In all animals there is a <u>principal lobe</u>; to which may be added a <u>right</u> and a <u>left lobe</u>, placed either to the sides of the principal lobe or behind it. The principal lobe itself may be divided into two or more portions. As a further complication the liver may possess a <u>right</u> and a <u>left lobule</u> attached to the base of the corresponding lobes or to the principal lobe. The left lobule is frequently divided into two portions, which bestride the lesser curvature of the stomach. These Duvernoy named cardiac and pyloric according to their relations. The right lobule is less frequently divided.

The human liver, according to Duvernoy, consists of a principal lobe only, with a prominence equivalent to the right lobule. It, therefore,

lacks

lacks a right lobe, a left lobe, and a left lobule. The so-called right and left lobes, admitted by the greater part of anthropotomists, but rejected by some, are no more than two portions of the principal lobe, separated, but only on the convex surface of the liver, by the falciform ligament.

In conclusion, Duvernoy discusses the reasons for differences in the form of the liver in different classes of animals. He inclines to the opinion that the character of the food, and the associated conformation of the stomach, have an influence in determining the external features of the liver. In man, where the rule would not apply, he seeks refuge in the supposition that it may be that the erect attitude is responsible for the peculiar form of the organ.

The question of the number, nomenclature, and homology of the hepatic lobes was considered, in 1861, by Rolleston (11). He was probably the first to make use of the falciform ligament as an important landmark in defining territories in animals other than man. The suspensory ligament is attached to the suspensory lobe, which, he says, is very frequently trifid; the ligament having one lobule to its left, subequal to a second lobule to its right -the central suspensory lobule. The fossa for the gall-bladder forms the right boundary of the central suspensory lobule, thus separating it from the right lobule of the suspensory lobe which extends from the cystic indentation to the free right edge of the entire lobe.

To the left of the suspensory lobe is another, rarely, if at all, deeply incised or indented -the left lobe; whereas a right lobe is divided into three secondary lobules -the superior right lobule, the right kidney lobule, and the lobulus Spigelii.

Rolleston's

Rolleston's suspensory lobe is clearly equivalent to Duvernoy's lobe principal, and his left suspensory lobule to the lobe principal gauche; but Rolleston strikes a blow at the pre-eminent importance conferred by Duvernoy upon the lobe principal, when he confesses himself inclined to consider that the left suspensory lobule (lobe principal gauche of Duvernoy) is wholly lost in such livers as those of man and the ruminants.

To Rolleston was ascribed by Flower the credit of having been the first to recognise the importance of the caudate lobe (right kidney lobule) which had previously been confounded with the Spigelian lobe of man by many anatomists. It is questionable if such credit is rightly bestowed, for we have seen that Duvernoy recognised and figured a distinct right lobule attached to the right lobe.

Owen (12), in 1868, criticises Duvernoy's view that the human liver is to be regarded as homologous with the lobe principal of quadrupeds; or, conversely, that the quadruped liver is equal to the human liver plus superadded right and left lobes. "Fissures", he asserts, "rather than lobes, are added to the "liver of quadrupeds".

Owen's conception of the divisions of the liver agrees fairly closely with that of Rolleston. In the majority of mammals, he remarks, a lobe is definitely mapped out by a deep cleft to the left of the suspensory fissure, and another to the right of the cystic fissure. This he names the cystic lobe, and is apparently the first to recognise its homology with the right portion of the left lobe and the left portion of the right lobe, including the cystic fossa, of the human liver. In most mammals, that part of the liver which lies to the right of the cystic lobe is subdivided into two or more lobules; while

while the left lobe more commonly retains its simplicity.

A most important contribution to the literature on the morphology of the mammalian liver was made by Flower in 1872 (13). Flower's scheme for the division and nomenclature of the different lobes is of such moment, and has received such wide acceptance, that its promulgation may be taken as marking a period in the history of hepatic research. Flower regarded the liver as divided into right and left segments by the remains of the umbilical vein and ductus venosus. Each segment is subdivided into lobes. To the left of the umbilical fissure is a left central lobe, bounded to the left by a left lateral fissure, beyond which lies a left lateral lobe. In the same manner the right segment is subdivided, by a right lateral fissure, into a right central and a right lateral lobe. To the right lateral lobe are appended Spigelian and caudate lobes.

Although the caudate lobe is large in some animals, and may even rival its neighbour, the right lateral lobe, in size, Flower did not give any name to the fissure which separates the two adjacent lobes. Some time ago, the present writer (8) suggested that it might with convenience be known as the right dorso-lateral fissure.

The cystic fissure, to which Owen attached some importance, was shown by Flower to be of no great morphological significance, since it is irregular in position and frequently absent. It may be of interest to add that the presence of the fissure does not depend upon the presence of a gall-bladder; for, in the horse, where a gall-bladder is not present, a "cystic fissure" is all but absolutely constant, and may even be double.

Valuable

Valuable as was Flower's scheme, and widely as it has been accepted, its publication did not at once lead to a complete unification of description and nomenclature. It was not always followed by writers of special monographs, and Krause (14) is a noteable example of those who did not become adherents of Flower. Although his "Anatomie des Kaninchens" did not appear until twelve years after the publication of Flower's views, Krause describes the liver according to a method of his own. He recognises four chief lobes; a median, a right and a left lateral, and a caudate. The median lobe he also calls the Lobus quadratus, on the assumption, apparently, that it is the homologue of the area of the human liver known by that name. In reality, Krause's median lobe corresponds to Flower's right and left central lobes. Krause's left lateral lobe agrees with Flower's, but he errs in describing it as composed of two secondary lobes -anterior and posterior. It was left for Brachet (15) to point out that the fissure which produces the subdivision appears very late in embryonic life, and may be very feebly marked even in the adult. Krause subdivided his right lateral lobe also, in consequence of being misled by the large size of the rabbit's caudate lobe, which he named the posterior right lateral lobe. Another error into which he fell was in giving the name of lobus caudatus to the Spigelian lobe.

Classic though Krause's momograph has become, it does not appear to have had an appreciable effect upon the conception of the morphology of the mammalian liver.

Prior to 1888, the year in which an elaborate and excellent paper by Rex appeared, anatomists other than microscopists had been satisfied to direct their attention

attention mainly to the exterior of the liver. Rex (10) struck out an entirely new line of research when he considered the arrangement of the branches of the portal vein, hepatic veins, and bile-ducts in their relation to the lobes. Unfortunately, Rex had not been able to consult Flower's paper, and so was constrained to adopt a different nomenclature. Perhaps this is not to be entirely deplored, as it permitted him to approach his subject with an unbiassed mind. In the generalised form of the mammalian liver he came to the same conclusion as Flower in the recognition of six lobes; but, unlike Flower, he did not attach great importance to the position of the umbilical vein as indicating a line by which the organ could be divided into right and left segments. Consequently, his middle lobe corresponds, not to Flower's central lobe as a whole, but to the right central only. He also raises the caudate lobe to a like morphologic plane with the right lateral lobe, and names it the right inferior lobe.

It is unfortunate that Rex uses a nomenclature not to be commended from the standpoint of the comparative anatomist. He regards the surfaces of the mammalian liver as compared with those of the human organ; and, consequently, speaks of a lobe as being "superior" or "inferior" as it would be were it transplanted into the erect human body.

Possibly the best assistance to an understanding of the descriptions of Rex will be obtained by placing his nomenclature side by side with that of Flower:-

Flower.

FLOWER.	REX.
Right central lobe.	Middle lobe.
Left central lobe.	Left superior lobe.
Right lateral lobe.	Right superior lobe.
Left lateral lobe.	Left inferior lobe.
Caudate lobe.	Right inferior lobe.
Spigelian lobe.	Lobus omentalis.

Apparently Rex was the first writer to use the name omental lobe in place of Spigelian lobe; an alteration which has much to commend it since it indicates the close relationship which exists between the lobe and the gastro-hepatic omentum.

The right and left main branches of the portal vein have a remarkably regular distribution, by means of secondary branches, in the various lobes of the liver of different species of mammals. This brought Rex to recognise that the lobes could be homologised, not only by an examination of the exterior, but also by the observation of the distribution of the principal branches of the vein. He discovered that from the right main portal branch two veins arise, to which he gave the names of ramus descendens and ramus arcuatus: the former supplying the caudate lobe (right inferior lobe), the latter, the right lateral lobe (right superior lobe). The left main portal branch, after contributing a ramus omentalis to the Spigelian or omental lobe, and a ramus angularis to the left lateral lobe, ends in a recessus umbilicalis, so named from its derivation from the umbilical vein of the embryo. From the umbilical recess two groups of braches, or arborisations, are distributed to the right central lobe on the one hand (right arborisation), and to the left central lobe on the other (left arborisation). The right central lobe has evidently a double venous supply; for to it also proceeds a

ramus

ramus cysticus, a branch either of the right or of the left main vein.

The following table shows at a glance the distribution of the portal vein as described by Rex. In order to avoid the use of an unsuitable nomenclature, the names of the lobes as suggested by Flower are here substituted for those of Rex, with the exception of omental in preference to Spigelian.

LOBES.	BRANCHES OF PORTAL VEIN.
Caudate.	Ramus descendens.
Right lateral.	Ramus arcuatus.
Right central.	Ramus cysticus. Right arborisation from recessus umbilicalis.
Left central.	Left arborisation from recessus umbilicalis.
Left lateral.	Ramus angularis.
Omental.	Ramus omentalis.

Since the distribution of the Bile-ducts does not enter into the province of the present research, it may be dismissed by simply giving the following table, from which it will be seen that the chief ducts, according to Rex, are three in number.

DUCT.	LOBES.
Right.	Right lateral, caudate and omental.
Middle.	Right part of right central.
Left.	Left part of right central, left lateral, left central, and omental.

It is obvious that the distribution of the bile-ducts of the adult can afford little assistance in the division of the liver into its primary lobes. An investigation of the development of the ducts, not yet undertaken, would be of great value; for it can scarcely

scarcely be doubted that considerable alteration occurs during their evolution in the embryo. A hint of this is given by the imperfect observations made by Brachet and Lewis, and those described later in the present communication.

Rex describes three hepatic veins, each arising in two branches, and draining the following lobes:-

Right (superior and inferior).	Right lateral and caudate.
Middle (right and left).	Right central.
Left (superior and inferior).	Left central and left lateral.

The importance of the contribution made by Rex to the question of the homology of the lobes of the liver in the mammalian series depends upon the circumstance that he was the first to point out that the distribution of the portal vein and the arrangement of the lobes are closely associated the one with the other; and that, even in animals in which the liver is more or less consolidated (as in cetaceans, ruminants, anthropoid apes, and man), the same number of branches of the portal vein can be detected. Thus, a final blow was given, were it necessary, to the assumption that the human liver has lost lobes, not fissures.

Subsequent observers, with the exception of Ruge and Cantlie, have been chiefly concerned in the examination of the vascular arrangement in the embryonic liver. Ruge (16) has investigated a great abundance of primate material, and his painstaking and valuable observations have been embodied in a series of papers published at intervals since 1902. He has described a number of secondary fissures and lobules

lobules which help to explain anomalous indentations and grooves occurring in mammals other than the primates. Among other points it may be noted that, because of their close association with the vena cava, he favours the inclusion of omental and caudate lobes under the common name of lobus venae cavae. Return will be made to this later. At the present moment, it is only necessary to remark that the name lobe of the inferior vena cava had previously been given by Brachet (17) to the caudate lobe.

Cantlie's contention (18) that the present method of dividing the human liver into right and left lobes by a line drawn along the longitudinal fissure is unscientific, and consequently untrue and untenable, has received little consideration at the hands of the human anatomist. He asserts that the gall-bladder is central, and on either side of it lie the true right and left lobes; and a line drawn from the fundus of the gall-bladder to the exit of the hepatic veins divides the liver into two equal portions as shown by injection, by weighings, by developmental, by pathological, and by clinical observations. Occasion will be taken later to show that he has certain grounds for stating that the present method is unscientific; but, at the same time, one is forced to confess that it is highly convenient.

This appears to be a fitting place at which to pause and gather together the main features of the various observations made up to the time of the publication of the paper by Rex. This can be most briefly done in the form of a tabular statement showing the divisions of the liver as given by the different observers.

(Table).

DUVERNOY.		ROLLESTON	OWEN	FLOWER	KRAUSE	REX
1835		1861	1868	1872	1884	1888
Principal lobe		Suspensory lobe	Cystic lobe	Right central Left central	Middle	Middle Left Upper
Right lobe		Superior right lobule	Right lobe	Right lateral	Anterior right lateral.	Right upper
Right lobule	Right lobe.	Right Kidney lobule		Caudate	Posterior right lateral	Right lower or lobus descendens.
Left lobule		Spigelian lobule	Spigelian	Spigelian	Caudate	Omental.
Left lobe		Left lobe	Left lobe	Left lateral	Left lateral	Left lower.

Thanks to investigations initiated by His (19), on the human embryo, and Hochstetter (20), on embryos of the rabbit, a considerable volume of literature has accumulated during the past few years. Seeing that the present communication does not relate to the earliest stages of hepatic development, it is not necessary to give more than a cursory resumé of what has been learned of the origin of the liver, and its relation to embryonic veins.

As is well known, a hepatic bud early (during the second week in the human embryo) developes from the epithelium of the gut, and surrounds and invades either one or both omphalo-mesenteric veins. The invasion of the veins by the hepatic tissue results in the production of the sinusoids of Minot (21), and the production of a complex stream-bed in place of the originally simple one. The omphalo-mesenteric veins, consequently, no longer communicate directly with the venous sinus of the embryonic heart; and so, were no other and more expeditious route provided for the passage of the blood, circulation would be impeded. But, as the production of sinusoids from the omphalo-mesenteric veins is proceeding, the umbilical veins are becoming larger, and of greater importance as affording a ready means by which the blood may reach the heart. Thus, the omphalo-mesenteric veins are relieved of a part of their duty.

At first the umbilical veins are not connected with the liver, but run past it to open directly into the ducts of Cuvier. Later, however, one vein, or both, is constricted and divided into two portions; a proximal, connected with the duct of Cuvier; and a distal, which becomes involved in the liver. The exact arrangement differs with the kind of animal. In the rabbit both veins are associated with the

liver

liver, and, for some time, the right is much the larger; as is also the right omphalo-mesenteric vein. Thus is caused, according to Lewis (22), a preponderance of venous channels on the right side, and a consequently more rapid development of the right part of the liver. It will be seen later that the same one-sided growth, arising from a like cause, is noticeable at a certain period in the development of the liver of the pig.

Sooner or later, in all animals, the right umbilical vein begins to disappear on the usurpation of its function by the left vein. In the human embryo, in the rabbit, and in the cat, the right vein early loses its association with the liver; and in the rat it seems probable that it never participates in the hepatic circulation, for, in a 5mm. embryo in which the lobes have developed to a considerable extent, the right umbilical vein is confined to the body-wall (Fig. 3o). A further variation is present in the sheep. From the research of Bonne (25), it seems that, in this animal, the two umbilical veins remain of the same size, and unite to form a common vessel which passes into the liver to be continued onwards by the ductus venosus.

Zumstein's notes (24) on the development of the hepatic vessels in the guinea-pig being somewhat brief and incomplete, it may be asserted that the most detailed observations on the growth of the veins of the liver of mammals other than man have been made on rabbit embryos.

A paper of considerable importance in connection with the investigations described in the present communication, is one published by Brachet in 1895 (15). In a rabbit embryo 12 days old, he describes the

the liver as being composed of three lobes. One of these is ventral in position, and occupies the continuation of the septum transversum into the ventral body-wall. The other two lobes -right and left lateral- have been developed in the septum transversum itself. At first, then, there are three lobes definitely separated from each other; but later a new subdivision occurs. The middle or ventral lobe is divided into two -a right and a left; and thus four lobes are produced. Neverthelesss, Brachet concludes that the liver of the adult rabbit consists of three fundamental lobes, namely, a median lobe, occupying the ventral part of the organ, and developed in association with the two umbilical veins; a left lateral lobe, proceeding from the primitive left omphalo-mesenteric lobe which develops along the vein of that name; and a right lateral lobe, having a like history and a similar developmental relationship to the right omphalo-mesenteric vein.

Brachet holds that the lobe of the inferior vena cava (caudate lobe of Flower, and posterior right lobe of Krause) is merely a prolongation of the right lateral lobe developed in the lateral mesentery. The Spigelian lobe is also simply an appendage to the right lateral lobe.

The chief interest of Brachet's communication depends upon the recognition that the liver follows the umbilical and omphalo-mesenteric veins during development, and that the direction and situation of those vessels govern the direction and situation of hepatic growth.

Swaen (25) and van Pée (26), also using rabbit material, have arrived at somewhat similar conclusions.

Up to 1906, no attempt had been made to connect the

the results of Rex's observations on the adult blood-vessels with the vascular conditions in the embryo. In July of last year, however, Mall (27) published a paper which bridges the gap so far as the human liver is concerned. In human embryos 5mm. and 6'5 mm. long, he shows that all the blood from the left umbilical vein passes through the liver, the direct connection of the vein with the heart having been lost. The right umbilical vein is also obliterated, and, therefore, the whole of the umbilical blood finds its way to the heart by way of intra-hepatic channels. To facilitate the passage of a large volume of blood through the liver, the right omphalo-mesenteric vein has either remained pervious, or has been re-opened; thus allowing of free circulation on the right side. On the left, two new veins have been formed, or they may have arisen directly from the remains of the left omphalo-mesenteric vein. At any rate, they are two of the permanent main vessels of the liver, namely, the vena hepatica sinistra and the ramus angularis; the latter having origin from the recessus umbilicalis.

During the fifth week of embryonic life, the right omphalo-mesenteric vein is partly converted into sinusoids, and the ductus venosus is formed. The ramus dextra of the hepatic vein, and the ramus arcuatus et descendens of the portal vein, then take the place of the former single and continuous channel. It seems that the time of disappearance of the right omphalo-mesenteric vein is not constant; for it is present, along with a ductus venosus, in an embryo 11 mm. long. In the same embryo (at the end of the fifth week), "the right and left portal twigs have "begun to divide, and from the recessus umbilicalis "a new group of veins have formed and radiate into the

middle

"middle and left lobes of the liver. On the hepatic "side the left branch has divided into two trunks "and two new branches have appeared: the vena cava "inferior and the vena hepatica media which has its "terminal right and left branches". .... "In "this case the liver is formed of four main lobules, "and with the subdivision of the middle and left "hepatic veins into two branches each, six primary "lobules are seen to correspond with the six primary "lobes of the mammalian liver". .... "With the "completion of six lobules we recognise fully the "adult form of the liver. Each lobule now represents "one of the six lobes of the mammalian liver; each "of the primary lobules radiate from a center and have "between them the main trunks of the portal veins; "each interlobular vein at this stage is to form a "main trunk in the adult".

That in the human embryo at a certain period of its existence there are six lobules is certainly evident from Mall's descriptions and exceedingly convincing illustrations; but that these lobules ultimately develope into six lobes, equivalent to the six lobes of the typical mammalian liver, does not seem to be beyond question. In order to count six lobes, the omental lobule and caudate lobe must be considered as constant and separate units in which a ramus omentalis and a ramus descendens respectively ramify, and from which hepatic veins spring. That the portal vein has a ramus omentalis is not satisfactorily shown in Mall's figures. Nor, it may be said, is the ramus descendens of the human liver absolutely certainly homologous with that branch of the portal vein which supplies the caudate lobe of mammals in general. It will be shown later that, in some mammalian embryos at any rate, independent rami omentalis

omentalis and descendens cannot be detected; and that even in an animal in which the omental lobule and caudate lobe are much larger than in man. It appears to the present writer, therefore, that judgment on this head should be suspended until further evidence is forthcoming.

Seeing that there is considerable paucity of information regarding the later development of the vessels of the liver, a research was instituted in the hope of adding something, however little, to the present knowledge of the origin and mode of production of the definitive hepatic veins. The mammal of which the most complete series of embryos was available was the pig. Of this animal, embryos have been examined from the 19th day of gestation up to a time close to birth.

The smaller embryos were cut into serial sections, and reconstruction models were made of the liver as a whole, and of the blood-vessels separately. In embryos older than 30 days, the liver is of sufficient size to allow of examination with a pocket-lens or the naked eye. In order to study the blood-vessels in such livers, the whole embryo was injected with dilute Indian ink (as suggested by Hill (28)) by way of the umbilical vein, and thick, free-hand sections were made of the liver. It was found that the main veins make their appearance comparatively early, and that after the 25th day, the only alteration which takes place in them is the formation of their smaller branches.

A few embryos of other mammals, such as the mole, the hedgehog, the calf, the sheep, and the rat, have been examined; but a series, sufficiently complete

to

to allow of a connected account of the development in these animals, could not be obtained. Nevertheless, they have been found useful for purposes of comparison.

DEVELOPMENT OF THE LOBES OF THE LIVER OF THE PIG.

It will facilitate the description of the growth of the blood-vessels if the development of the lobes of the liver of the pig be first considered.

In the liver of the adult pig there are all the typical mammalian lobes; but the caudate lobe is not very large, and the omental lobule is rudimentary. A deep umbilical fissure divides the central lobe into right and left portions. If the liver be examined as it lies in the abdomen, the gall-bladder appears to occupy the umbilical fissure: that is, there is no "quadrate lobe" visible on the surface. Of the two lateral lobes, the left is generally much the larger.

Unfortunately, the liver of the youngest pig-embryo which I possess has already developed so far as to be composed of three lobes. It would have been much more satisfactory could material have been obtained to show the more early stages of development. Nevertheless, the information which can be gathered from the models of those embryos which were available is of some value, as subsequent description will show. Furthermore, the development of the definitive blood-

vessels

vessels has barely begun in the youngest embryo examined.

<u>6 mm. embryo.</u> In a 19 days' embryo (comparable to No. 68 of Keibel's Normentafel (29)) three definite lobes are present; the fissures separating them being deep (Fig. 1). The major part of the whole liver is formed by a central lobe, absolutely devoid of the slightest indication of a subdivision into right and left portions, and mainly embedded in the septum transversum which encloses it to the very verge of the fissures by which it is separated from the lateral lobes. On its caudal (intestinal) surface are two grooves occupied by the two umbilical veins; and midway between them is a third groove lodging the rudiment of the gall-bladder and cystic duct (Fig. 13). That is to say, the central lobe is practically symmetrical in relation to the Anlage of the gall-bladder; the symmetry being rendered all the more obvious by the presence of two umbilical veins about equidistant, one on each side, from the gall-bladder.

The lateral lobes are more dorsal in position, and unequal in size. They both project into the peritoneal cavity, and may be regarded as off-shoots from the central lobe. The right lobe is larger than the left (Fig. 1); a prepondarance in volume dependent upon a more spacious series of venous channels, as will be seen when the veins come to be described.

cribed. It is quite possible that the right lobe is greater than the left from the very beginning. This supposition finds support in the known fact that in some mammals -the rabbit, for example- the right umbilical vein is greatly superior, in point of size, to the left; thus producing an organ the right side of which developes more rapidly than the left (cf. Lewis (22)).

The shape of the two lateral lobes is also different. The surfaces of the right lobe are almost entirely convex; whereas, the mesial surface of the left lobe is concave in conformity with the opposed convex surface of the stomach.

5 mm. (22 days') embryo. In this embryo, the central lobe resembles very closely the same lobe in the younger specimen. It is, however, gradually becoming freer from the septum transversum and consequently much more of its surface is now covered by peritoneum. Its symmetrical form is rather less obvious as the result of a certain amount of depression of its cephalic face caused by the heart. Furthermore, the intra-hepatic portion of the right umbilical vein has been much reduced in calibre in the interval which has elapsed between the 19th and 22nd days of development. At the same time, there are still two veins placed one on each side of the groove in which the gall-bladder lies (Fig. 20).

The

The lateral lobes have undergone several marked changes. The right is now scarcely, if at all, larger than the left; and its form is modified in consequence of its close association with the vena cava, along the ventral surface of which hepatic tissue has begun to develope. The mesial surface of the left lobe is no longer merely co-extensive with the opposed surface of the stomach, but has expanded dorsalwards beyond the limits of the fossa in which the stomach lies; and, at the same time, gro th has resulted in the production of an obtuse projection at the ventral mesial angle of the lobe. The morphologic importance of this projection will be more evident in older embryos. It will suffice here to say briefly that there can be little question that it represents the rudiment of a processus pyramidalis such as has been described by Ruge (18) in the primates, and demonstrated by Thompson and Taylor (30) in the human liver.

Lewis (31), in his description of the anatomy of a 12 mm. pig embryo, states that the liver consists of four large lobes which were visible before the embryo was sectioned. Although no embryo between 8 mm. and 15 mm. has been examined, it is safe to suppose that a 12 mm. embryo will not be so remarkably different from those slightly younger or slightly older as to possess a greater number of hepatic lobes. Neither the 8 mm. nor the 15 mm. embryo has more than three lobes. It can only be concluded, therefore, that

that the specimen modelled and described by Lewis possessed an unusually divided liver.

15 mm. (25 days') embryo. No feature of the liver of a 15 mm. embryo, and of the one next to be described, is more striking than the large proportion of it formed by the central lobe (Fig. 2). That the whole organ has developed rapidly is indicated in many ways; but the rate of growth of the central lobe has greatly exceeded that of the lateral lobes. This being so, the central lobe has increased the lead, in regard to its volume, which it had in the younger embryos. There is, however, not the slightest indication of its subdivision into two parts.

The extra-hepatic portion of the right umbilical vein having disappeared, there is a single deep groove on the caudal surface of the central lobe, to the left of the gall-bladder, in which the left vein is lodged (Fig. 2). The gall-bladder in the 19 days' embryo reaches slightly beyond the most ventral limit of the liver. In the next older embryo, it just fails to reach this limit; and in the 15 mm. embryo its blunt, blind extremity lies some little distance from the margin of the liver. The same remark holds good for older specimens, and also for the adult pig. This points to the conclusion that the liver and gall-bladder do not grow ventralwards at the same rate, and will perhaps account for the absence of a groove in the liver, such as Thomson (4) has described as

formed

formed, in the human embryo, in preparation to receive the gall-bladder during its growth in length.

The caudal or intestinal surface of the central lobe has become very uneven; partly on account of depressions for the reception of surrounding viscera; and partly form the production of three incipient outgrowths of some importance from their character and fate in older embryos. One of these projections is placed to the left of the dorsal end of the groove in which the left umbilical vein is accomodated (Fig. 2. paraum. loo.). The second prominence is in the form of a rounded eminence between the umbilical vein and the gall-bladder; and is connected with the first-mentioned by a bridge of liver substance crossing over the vein and so spanning the valley along which it runs. The third projection is, as yet, very slight and lies immediately to the right of the gall-bladder.

The two lateral lobes are approximately of the same size. The shape of the left lobe has not materially altered, though the processus pyramidalis is more prominent than in the 8 mm. embryo. In the right lobe a fair amount of growth has taken place along the vena cava, and between this and the portal vein. In brief, the rudiment of the caval lobe (Ruge) has come into existence. Just ventral to, and to the right of the place where the portal vein enters the liver, there is a rounded projection which may be of moment (Fig. 2. p-c. lob.) if, as is conjectured, it corresponds to the praecaudate lobule

present

present in the liver of some primates (cf. Ruge (16)).

<u>25 mm. (30 days') embryo.</u> The central lobe still forms a large proportion of the entire liver; a feature best appreciated when the organ is viewed from the thoracic side. Not until now has there been the least sign of a subdivision into right and left central lobes; and even now there is only a shallow groove along the bottom of which the falciform ligament is attached (Fig. 3).

The depression produced by the umbilical vein is deeper than before; as is also, in a minor degree, that for the gall-bladder. The three projections from the intestinal surface of the central lobe, previously mentioned, are much more prominent than in the 15 mm. embryo. That to the left of the umbilical vein is particularly conspicuous; and that to the right of the gall-bladder has developed from a mere elevation into a veritable process (Fig. 3. d-v. lob). The prominence between the vein and the gall-bladder, though less obtrusive than the other two, is, nevertheless, a conspicuous feature on the surface of the central lobe.

Of the two lateral lobes the left is now somewhat the larger; so there is an advance towards the adult size-relationship (Fig. 3). Of the form of the left lobe it will suffice to say that the gastric depression forms a small proportion of the caudal surface as compared with former conditions; and that the

the processus pyramidalis has increased in size and has become blunt at its apex.

The caval loop is now of fair size, and a groove, corresponding to the portal vein in position, produces a partial subdivision into a processus papillaris and a caudate lobe. Ventral to the rudimentary caudate lobe is a projection of the right lateral lobe similar to the one already mentioned in the liver of the 15 mm. embryo.

In this embryo, then, there are five projections grouped around the portal fissure. Two of them belong to the central lobe; one, the processus pyramidalis, to the left lobe; and two to the right lobe. Of the last-mentioned, one, the caval lobe, is partly subdivided in consequence of its position astride the portal vein. A sixth projection -to the left of the umbilical vein- though not in close relationship to the portal fissure, is within a short distance of it. From the circumstance that they grow towards the portal fissure, and, by so doing, render it relatively less spacious and deeper, one is tempted to apply the name of "portal opercula" to these six projections. Before doing so, however, it would be necessary to discover if similar "opercula" develope and behave in a like manner in the embryonic liver of of other mammals. The material at my disposal, though not demonstrating the contrary, is not sufficiently abundant to permit of any generalisation.

In order

In order to facilitate description, it will be well to say here that there seems great probability that the various prominences mentioned above are homologous with certain lobules described bo Ruge as occurring in the liver of certain of the primates. The homology of the projection already referred to as the processus pyramidalis appears to be beyond question; and the processus papillaris need not be further discussed. The prominence springing from the central lobe to the left of the umbilical vein seems to be comparable to the lobulus paraumbilicalis (Fig. 3. paraum. lob.); the subsequent flattening which it undergoes, and its growth in a ventral direction, bringing it into a position quite similar to that figured by Ruge.

The projection between the gall-bladder and the umbilical vein may be referred to -for convenience only- as the "quadrate lobule" (Fig. 3. q. lob.). The eminence lying immediately ventral to the caudate lobe is most likely equivalent to the lobulus praecaudatus (Ruge) of primates (Fig. 3. p-c. lob.). This is all the more probable since, in some embryos, its lateral boundary is defined by a fissure occupying a position very like that of the fissura praecaudata (Ruge) of the monkey's liver.

The prominence to the right of the gall-bladder does not seem to be represented in the material examined by Ruge. Its importance is not very great in older embryos, and, therefore, little attention need

need be paid to it at present. If it is necessary to give it a name for purposes of reference, it might be called the dextro-vesical lobule (Fig.3. d-v. loo.)

The livers of embryos larger than 25 mm. were not modelled, as they are sufficiently large to be examined by the naked-eye. It is scarcely necessary to give a detailed description of each specimen, since they all follow the same lines of development. A general survey will suffice. A 52 mm. embryo has a liver very similar to that of the 25mm. embryo; the only differential points of moment being an increased prominence of the processus pyramidalis and a greater distinctness of the praecaudate lobule. In larger embryos the central lobe retains its relatively large size, and the notch for the umbilical vein on its ventral border becomes deeper. In the oldest embryos examined a fissure extends from the notch for some distance into the lobe; thus producing the separation, present in the adult, into a right and left central lobes. At no time, however, can the fissure be said to rank with those limiting the right and left lateral lobes. Independent of its comparative shallowness, it differs from the lateral fissures in its lateness of appearance, and in the manner of its production.

The history of the processus pyramidalis in embryos larger than 52 mm., consists in its becoming less and less projecting, and more and more flatten-

ed against

ed against the rest of the left lateral lobe, consequent upon the increase in the size of the stomach and correlated increased in the extent of the fossa in which it lies. But, in spite of the resultant flattening, it does not lose its independent character.

As has been related, in the younger embryos the praecaudate lobule gradually became more distinct and projecting; but from an 80 mm. embryo onwards it is compressed against the rest of the right lateral lobe. The compression begins in the shape of a groove for the duodenum, which gradually increases in width until the whole lobule is involved. In some embryos (122 mm.,for example) the lobule is represented by a flattened area, ventral to the caudate lobe, continuous to the right, without line of demarcation, with the bulk of the right lateral lobe. In most embryos, however -notably in that of 150 mm.- a decided fissure forms its right boundary. From its variability in the embryo, and from its inconstancy in adult primate livers, it must be concluded that the praecaudate lobule is not of so much importance as is the processus pyramidalis. Though, in the embryo, it forms an appendage to the right lobe comparable to the pyramidal process of the left, its close proximity to the portal vein precludes it from equalling the processus pyramidalis in magnitude and independence.

The process of the central lobe which has been considered above a being equivalent to Ruge's lobulus

paraumbilicalis

paraumbilicalis, shares in the general depression produced by the adjacent hollow viscera. At the same time it grows over the umbilical vein, and extends towards the ventral border of the liver.

The "quadrate" and dextro-vesical lobules present little of interest in the older embryos. They are represented simply by flattened areas extending towards the portal fissure, one on each side of the cystic duct. Though their importance in the pig is not very great, they are evidently of much more moment in some mammals.

The fissure bounding the caudate lobe -the right dorso-lateral fissure- just reaches the margin of the liver in an 86 mm. embryo; and in an embryo measuring 122 mm. in length it crosses the margin. It clearly developes in the same manner as do the right and left lateral fissures: that is to say, it is produced in consequence of the growth in extent of the lobes between which it lies.

From the above it may be contended that the mammalian liver consists of three lobes only. In the pig, and probably in all other mammals, the main or central lobe is, at first, considerably greater than the sum of the other two lobes; and it is not until the adult form has been attained that its volume fails to constitute half of that of the liver as a whole.

The

The central lobe, moreover, is really only one lobe, and not two as described by Flower. In those mammals in which a right and a left central lobe have been determined, the division is, so to speak, accidental, and the result of the presence of an umbilical vein. In some animals, the growth of hepatic tissue being luxuriant in its neighbourhood, the vein becomes completely surrounded by liver from the occurrence of a complete fusion of the tissue of the paraumbilical and "quadrate" lobules. In others, such a fusion is either absent or incomplete, and an "umbilical fissure" is the result.

The "umbilical fissure", therefore, cannot be allowed to rank as a true line of separation of the central lobe into two parts. Nor does it mark the true morphologic line of division of the liver into right and left segments. Except in those animals in which the two umbilical veins fuse into one -and such fusion is apparently of rare occurrence- the embryonic median plane lies to the right of the "umbilical fissure". In mammals like the pig, in which both umbilical veins are involved in the liver, it is obvious that the true line of union of right and left moieties must lie somewhere between the two veins. There seems little reason to doubt that it coincides in position with the gall-bladder and cystic duct, which also mark the original line of attachment of mesogastrium; and there seems good reason for assuming that

that the "quadrate lobe" really belongs to the left half of the liver.

That the contiguous viscera, solid as well as hollow, have a profound influence in moulding the liver is undoubted. Toldt and Zuckerkandl (32) have clearly demonstrated that the pressure of even so small an object as the gall-bladder may produce atrophy of liver-tissue. But there is no convincing evidence to show that the adjacent organs have any influence whatever upon the production of the two lateral fissures by which the liver is divided into its three primary lobes. Duobtless the projections of liver-substance to which attention has been directed, are produced in the first place by growth along lines of least resistance. But, as has been said, with the exception of the papillary process and the caudate lobe, they early cease to be projections, and are compressed by the superposed organs; and at no time do they contribute to the essential morphology of the liver. The caval lobe should hardly be classed along with objects like the pyramidal process, since it developes along the vena cava and its mesentery; whereas the other projections of the primary lobes do not follow either a vessel or any other structure.

An interesting feature in the development of the lateral fissures has been observed. It appears from certain embryos, notably the 15 mm. pig embryo

and

and the 11 mm. hedgehog embryo, that the hepatic tissue of the different lobes is separated by a thin layer of mesoderm even before the actual fissures make their appearance. Or, in other words, the fissures do not cut a primitively common mass into lobes, but develope along lines of mesoderm which form septa between lobes really independent from an earlier period of development. So far as can be gathered from an examination of the literature, this feature of development seems to have escaped observation. In what measure it affects the question of the causation of fissures, can hardly be determined in the absence of more extensive investigations. It would be of the greatest interest to examine the early stages of development of a consolidated liver, with a view to the discovery of similar mesodermic septa.

DEVELOPMENT OF THE BLOOD-VESSELS OF THE LIVER OF THE PIG.

The development of the lobes having been sketched, the way is prepared for the consideration of the process of growth of the blood-vessels.

6 mm. (19 days') embryo. In this embryo there are two umbilical veins which, though the left is slightly the larger, have nearly the same calibre prior to their entrance into the liver. Some little distance before they reach the liver the two veins approach each other very closely, without, however, effecting

effecting an actual inter-communication (Fig. 15). The intra-hepatic portion of the left vein has a much more considerable volume than has the corresponding part of the right vessel. At this stage, in the absence of a ductus venosus, the left vein terminates rather abruptly in the vicinity of the oesophageal notch of the liver. In the light of subsequent development, it is necessary to point out that a small vessel arises from the termination of the left umbilical vein and passes into the substance of the left lateral lobe (Fig. 4. a.). This will be further considered in connection with older specimens.

A short distance from its termination, a vessel is connected with the right side of the left umbilical vein, and a branch leaves it to the left. The connection on the right is with the right omphalo-mesenteric vein, and the branch to the left is doubtless the remains of the left vein of the same name (Fig. 4. l. o-m. v).

Within the liver the right umbilical vein follows a course parallel to that of the left vein. It ends by joining the omphalo-mesenteric vein at the point where this vessel divides into right and left branches (Figs. 4 & 12. r.u.v.); or, it would possibly be more correct to say that, a short venous channel leaves the omphalo-mesenteric vein at its point of division and runs forwards (cephalwards) to join the termination of ion of the umbilical vein.

The two omphalo-mesenteric veins are represented by a single vessel which pursues the customary spiral course over the dorsal surface of the intestine, in order to enter the liver. Immediately on its entrance it divides into two main branches. The larger one, to the right, follows the curvature of the surface of the right lateral lobe, in the form of a large, laterally flattened channel which finally joins the duct of Cuvier without any interruption whatever (Fig. 4. r.o-m.v.). It, beyond doubt, represents the right omphalo-mesenteric vein; but whether it is a re-opened channel, or one which has never been interrupted, lack of younger material leaves open to question.

The left branch of the omphalo-mesenteric vein, even in the oldest embryo examined, is not completely embedded in the liver, but runs in a groove, more or less deep, on the surface. It joins the left umbilical vein close to its termination, and opposite the vessel described above as a branch of the umbilical vein destined for the left lateral lobe. It seems probable that this is the vestige of the left omphalo-mesenteric vein, support being afforded the supposition by the circumstance that it has a narrow, but unmistakable, connection with a rudimentary vena hepatica sinistra. If this surmise be correct, the left omphalo-mesenteric vein pursues a course closely comparable to that to that of the right vein. That is, it follows a curved path conformable to the surface of the left lateral lobe.

From what has just been said, it is evident that, as yet, there are no independent hepatic veins; but, the proximal part of the left omphalo-mesenteric vein having become almost completely detached from the rest, there is a rudiment of the vena hepatica sinistra (Fig. 4. v.h.s.), which, even at this early period, shows indications of a division into two branches --one for the left lateral lobe, the other for the central lobe. A short and rather thick vessel leaves the central lobe to join the termination of the right omphalo-mesenteric vein. Later it becomes the vena hepatica media as described in this communication (Fig. 4. v.h.m.).

The 19 days' pig embryo, then, affords corroborative evidence in favour of the conclusion, arrived at by Brachet (15) and restated here as the result of the observation of the development of the hepatic lobes, that the liver is fundamentally composed of three lobes. The central of these is associated with the two umbilical veins; and the right and left lateral lobes are developed in connection with the right and left omphalo-mesenteric veins respectively. Furthermore, because the hepatic veins are produced from the omphalo-mesenteric veins, they primarily belong to the lateral lobes. Those vessels which ultimately

ultimately drain the central lobe are of later development.

8 mm. (22 days') embryo. There are still two umbilical veins, but the duty of the intra-hepatic portion of the right vein has clearly been taken over, in part, by the left. Its extra-hepatic portion is of good size (Fig. 23), but mainly connected with the vessels of the body-wall. In the younger embryo the two umbilical veins approach each other very closly before entering the liver. In the 8 mm. embryo there is a considerable inter-communication between them at the place where the right vein is about to enter the liver (Fig. 22). As a consequence, the intra-hepatic part of this vein is comparatively slender (Figs. 5, 20 & 21. r.u.v.), though easily recognised and traced to its union, as in the younger specimen, with a vessel arising from the point of bifurcation of the omphalo-mesenteric vein.

The communication between the two umbilical veins is of interest as indicating a similarity of development in the marsupials and in the higher mammals. McClure (33) has described the formation of two communications in an 8 mm. embryo of Didelphis marsupialis; one at the umbilicus -whereby an umbilical sinus is produced; the other on the ventral surface of the liver, by which another sinus is formed. After the formation of the second sinus, the two vessels pass "through the parenchyma of the liver in a channel common

"common to both which opens into the post-cava in com-
"mon with the left hepatic vein". In regard to 11'5 -12 mm. embryos of Didelphis, McClure says that there is one large umbilical vein forming the principal channel between the allantois and the liver; "a vein "which I regard as the left umbilical vein. This "large vein lies in the ventral body-wall slightly "to the left of the mid-ventral line, and to the right "is situated a much smaller vessel which is difficult "to follow in consecutive sections, but which is pro-"bably the remains of the right umbilical vein. The "two umbilical veins appear to anastomose in places "with each other, so that one might almost regard "the larger of the two veins as being formed, in "places, through the fusion of the two umbilical veins".

Broom (34) gives a comparable account in his description of an 8'5 mm. Trichosurus embryo, where he states that one vein carries the blood from the allantois to an umbilical sinus from which two large umbilical veins pass into the liver.

These observations on the vessels of marsupial embryos tempt one to regard the much narrower communication in the pig as being of like nature in a minor degree. Bonne (23) is of opinion that the single intra-hepatic vein of the sheep is formed by the fusion of the two umbilical veins; or, as one may say, the fusion is carried to a much farther extent than in marsupials. There is, however, the bare possibility that the right vein may dwindle in the sheep in

the same

the same manner as in Didelphis, and that Bonne may have failed to detect it. This, naturally is a mere supposition. Whatever may be the arrangement in the sheep, there is an anastomosis between the two veins in the pig, established about the time at which the intra-hepatic portion of the right vein becomes narrow prior to losing its continuity with the extra-hepatic part.

A ductus venosus has now been formed (Figs. 5 & 16. d.v.). The establishment of a more direct route along which the blood may travel on its way to the heart, has resulted in a very definite interruption in the continuity of the left omphalo-mesenteric vein. and the production of an independent vena hepatica sinistra (Figs. 5 & 17. v.h.s.).

A number of small branches leave the left side of the intra-hepatic course of the left umbilical vein, some of which become definitive vessels and form the left arborisation from the recessus umbilicalis of Rex (Fig. 5. l.a.). It should be noted that, as in the 6 mm. embryo, a small short branch arises from the umbilical vein at the point where it joins the ductus venosus (Figs. 5 & 17. a.).

The right omphalo-mesenteric vein is similar to that of the previous mebryo, except that it has become more involved in the formation of sinusoids. In this embryo, the branch to the left -joining the left umbilical vein- is relatively narrow; but this is probably of no significance. The right branch calls

calls for no remark beyond that it is connected, by means of small channels, with the vena cava, along which a caudate lobe has begun to develope. The third branch of the omphalo-mesenteric vein, leaving the point of bifurcation into right and left main branches, joins the termination of the right umbilical vein as it does in the 19 days' embryo. From the place of union a moderately large channel passes forwards (cephalwards) in the substance of the central lobe.

There is now an independent vena hepatic sinistra, and also a vena hepatica dextra formed by dorsal and ventral tributaries (Fig. 8. v.h.s. & v.h.d.). The dorsal right vein is within the right lateral lobe where it is continuous, by means of a series of large channels, with the right omphalo-mesenteric vein. The ventral tributary of the right hepatic vein drains the right portion of the central lobe. In addition there is a third, rudimentary hepatic vein taking origin in the middle part of the central lobe and constituting the forerunner of the vena hepatica media (Fig. 8.v.h.m.).

The preponderance, in this embryo, as well as in the younger one, of the right lateral lobe over its fellow, depends upon its great richness in venous channels. It is only when the vascularity in the two is more nearly balanced that the left lateral lobe begins to assume the relatively greater bulk.

15 mm.

15 mm. (25 days') embryo. The extra-hepatic portion of the right umbilical vein no longer communicates with the vessels in the interior of the liver. It is mainly concerned in the vascular supply of the body-wall; but there is still a narrow connection between it and the left umbilical vein (Fig. 31. a.). The left vein is large, and, as before, contributes a number of moderately capacious branches to the left and anterior (cephalic) parts of the central lobe in shape of a left arborisation of Rex (Figs. 7 & 30. l.a.). A few smaller vessels pass towards the right; that is to say, the right arborisation has begun to form (Fig. 7. r.a.).

Close to the point at which the left umbilical vein becomes continuous with the ductus venosus, a ramus angularis takes origin and passes into the left lateral lobe, where its branches lie dorsal to those of the dorsal left hepatic vein (Figs. 7 & 25. r.ang). There seems good reason for supposing that the ramus angularis of the pig is not developed from the remains of the left omphalo-mesenteric vein. The vestige of the last-named vessel is clearly recognisable as arising ventral to the end of the umbilical vein, and traversing the left lateral lobe on about the same level as the smaller twigs of the dorsal left hepatic vein (Figs. 7, 28 & 29. l.o-m.v.). The ramus angularis, then appears to be produced by the growth of the small branch which has been described in the

younger

younger embryos as springing from the umbilical vein close to its termination. If this view be correct, the development of the ramus in the pig differs from that described by Mall as occurring in the human embryo.

The portal (omphalo-mesenteric) vein divides, as before, into right and left main branches. The left joins the umbilical vein as previously; and the right has become a ramus arcuatus no longer continuous with the dorsal right hepatic vein (Figs. 7 & 25. r.arc.).

In the two younger embryos a third vessel has been described as having origin from the omphalo-mesenteric vein at its point of bifurcation, and joining the intra-hepatic part of the right umbilical vein. In the 15 mm. embryo the vessel is of good size, and its homology with the ramus cysticus of Rex is byond doubt. It possesses a ventral branch running downwards (ventralwards) in the central lobe, comparatively close to the surface, and just to the right of the cystic duct (Figs. 7. 29 & 30. r.cys.). How much of this may have been formed from the right umbilical vein is difficult to say; but its position and general disposition are such that one can hardly avoid the supposition that some of it, at least, is the direct descendant of part of the umbilical vein (compare Figs. 21. r.u.v. and 29. r.cys.).

A short cephalic branch leaves the ramus cysticus close us close to its origin, and immediately divides into right and left twigs which are placed in the central lobe one on each side of the ventral right hepatic vein.

All the main hepatic veins are now clearly defined. The right vein divides into a dorsal and a ventral branch; the former draining the right lateral lobe, the latter proceeding from the right part of the central lobe. The left hepatic vein is similarly disposed on the left side of the liver. A middle hepatic vein commences as right and left tributaries and terminates very close to the end of the left hepatic vein (Figs. 8. 27. 28. 29 & 30).

25 mm. (30 days') embryo. The vessels of this specimen do not demand a detailed description, since, in the main, they resemble those of the 15 mm. embryo. Numerous fairly large vessels arise from the left and anterior (cephalic) sides of the umbilical vein (the left arborisation from the recessus umbilicalis of the adult); and a few branches of notable size have developed from the right side of the vein. It is obvious that, though a left arborisation is beginning to form as early as the 22nd day, a corresponding right group of vessels is of somewhat later development.

The ramus angularis and ramus arcuatus are both large, but the arcuate branch is somewhat the bigger. The ramus cysticus at its origin is not much smaller than the other portal branches; and its disposition

position is very similar to that of the same vessel in the 15 mm. embryo.

As there has been merely an increase in the size and in the number of branches of the hepatic veins, no call is made for special remarks regarding them.

It is worthy of note that, so far as the embryos under consideration are concerned, neither ramus descendens nor ramus omentalis can be detected. The caudate lobe and the omental lobule contain no vessels larger than sinusoids; a circumstance probably to be associated with the fact that these portions of the embryonic liver of the pig are but poorly developed.

DEVELOPMENT OF THE LOBES AND VEINS OF THE LIVER IN OTHER EMBRYOS.

The rest of the available embryological material is somewhat scrappy, but there are some embryos of the mole, hedgehog, and ruminants which are not without interest. The liver of the adult mole and hedgehog forms a good representative of that of a generalised mammal, inasmuch as all the lobes are well developed and separated by deep fissures. The ox and sheep, on the other hand, have a comparatively consolidated liver, but with a well-marked caudate lobe and a fairly large processus papillaris.

Mole

mole embryos. As far as my material admits of conclusions, it appears that the lobes are formed in the mole at a comparatively early period. In embryos 7 mm. in length they are all present; and in a 13 mm. embryo they have a form not unlike that of the adult lobes.

The central lobe forms rather less than half of total bulk of the liver, and is virtually undivided. The left umbilical vein is entirely surrounded by hepatic tissue, and there is consequently no umbilical fissure. The enclosure of the vein has obviously been caused by the coalescence and complete fusion of the two processes described in connection with the 25 mm. pig embryo as paraumbilical and "quadrate" lobules.

The mole differs from the pig in having a cystic fissure cutting the ventral border of the central lobe on a level with the gall-bladder.

The liver of a 13 mm. mole embryo has two large lateral lobes, almost equal in size. A processus pyramidalis is not very obvious; but there is a conspicuous projection in the same position as the praecaudate lobule of the pig. The most striking difference between the liver of the mole and that of the pig is the large size of the caudate lobe and the processus papillaris of the former.

The arrangement of the branches of the umbilical and

and portal veins is much the same in the mole and the pig. The ramus angularis, ramus arcuatus and ramus cysticus have the same general disposition. The ramus cysticus of the mole runs forwards (cephalwards) for a short distance and then divides into a branch which continues the direction of the parent vein, and a ventral branch lying practically parallel to, and to the left of, the cystic duct. This corresponds to that branch which has such a strong resemblance to the intra-hepatic portion of the right umbilical vein in the pig. It is perhaps worth mentioning that the ramus arcuatus divides into two branches; one curves upwards dorsal to the vena hepatica dextra; the other runs almost entirely towards the right. The latter is, to a certain extent, represented in the pig; but its volume in this animal is not nearly so great as in the mole.

The hepatic veins of the mole are somewhat diff-erent from the corresponding vessels of the pig. There are really only two veins -a right and a left- each having a dorsal and a ventral branch belonging respectively to a lateral and part of the central lobe. In addition each vein receives a third vessel apparently homologous with one of the tributaries of the vena hepatica media of the pig (Fig. 9).

Since the mole has a large caudate lobe, a ramus descendens was carefully sought; and a small branch, no doubt homologous with the ramus as descr-

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ibed by Rex was found leaving the portal vein close to the origin of the ramus arcuatus and ramus cysticus (Fig. 33. r.desc.). This, however, does not form the only vascular supply for the lobe, for there are several smaller channels running into it from various adjacent parts of the portal vein. No definite ramus omentalis could be discovered.

According to the conclusions arrived at by Rex, the caudate lobe should be drained by the right hepatic vein; but in the mole embryos examined the blood from the lobe finds its way, by several small venules, directly into the vena cava, much as it does in the pig.

Hedgehog embryo. It is rather surprising to find, in a hedgehog embryo of 11 mm. in length, that the right omphalo-mesenteric vein is not yet interrupted; or, if it has been interrupted at an earlier stage of development, it has been re-opened, and is represented by a very capacious channel uniting the ramus arcuatus and the right hepatic vein (Fig. 24). The presence of a continuous passage is all the more striking because of the advanced stage at which development of the lobes and vessels has arrived.

A ramus cysticus arises from the left main branch of the omphalo-mesenteric vein about mid-way between its origin and its union with the umbilical vein (Fig. 34. r.cys.). As in the mole, a ramus

descendens

descendens leaves the omphalo-mesenteric vein in common with the ramus arcuatus, and supplies the large caudate lobe (Fig. 34. r.desc.).

The absence of a ramus omentalis in the mole has been remarked. In the hedgehog, a short vessel, rapidly terminating in sinusoids in the papillary process, was observed and taken as being the beginning of a ramus omentalis. It leaves the left main branch of the omphalo-mesenteric vein almost exactly opposite the origin of the ramus cysticus (Fig. 34. r.oment.).

In the arrangement of the hepatic veins, the hedgehog resembles the pig more closely than the mole. Instead of there being two separate middle veins, each terminating in common with the other hepatic vein of its own side, as in the mole, there is one middle vein ending in company with the left hepatic vein, as in the pig.

It should be remarked that a considerable amount of blood is drained from the right lateral lobe by means of a number of fairly large veins which open directly into the vena cava.

Calf embryos. In the adult ox or sheep the vestige of the umbilical vein is completely embedded in the liver; but in the calf, a short time before birth, there is a decided "umbilical fissure". That is, the paraumbilical and "quadrate" lobules have not completely fused over the vein. The rest of the liver of such a calf has practically all the adult features.

The large caudate lobe is supplied by a relatively wide ramus descendens, which, as in the mole and hedgehog, leaves the right main portal branch at nearly the same point as a ramus cysticus of good size and a small ramus arcuatus. A ramus angularis is easily demonstrable, but presents no peculiarities of moment.

The hepatic veins are three in number -right, middle and left. The left and the middle veins join the vena cava close together, and are not formed by two large tributaries, but receive a number of small vessels at intervals. The right vein is different. It opens into the vena cava some distance caudal to the termination of the middle and left veins, and is formed by two tributaries, one draining the caudate lobe, the other coming from the equvalent of the right lateral lobe.

Clearly the distribution of the hepatic veins of the pig, mole, hedgehog, and calf does not follow a common plan; nor does it entirely consist with the generalised statement of Rex . The most important differences are connected with the vessel which has been named vena hepatica media in the above descriptions. In the ruminant it comports itself according to the method enunciated by Rex. In the mole and pig, however, one of its tributaries drains the central lobe, this evidently being equivalent to the <u>vena</u>

<u>hepatica</u>

<ins>hepatica media accessoria</ins> of Rex, who describes it as taking origin in, and receiving vessels from, that portion of the central lobe which lies to the left of the stem of the ramus cysticus. If Rex be followed in this connection, the vena hepatica dextra of the pig and mole -and possibly also in man (cf. Mall)- is not formed by dorsal and ventral rami, and does not drain a district of the liver on the right similar to the area of drainage of the left vein. No doubt a more satisfying conclusion could have been arrived at had further embryological evidence been forthcoming; but the interpretation as given in the preceding paragraphs appears to be satisfactory so far as information is available.

Only in the mole does the vena hepatica media depart from the arrangement present in the other embryos. In the pig, hedgehog and calf, it terminates in common with the left hepatic vein; whereas, in the mole it is apparently represented by two veins, one joining the right and one the left hepatic vein. It must, however, be remembered that the vessels of only one mole embryo were modelled. It is possible that, had others been similarly investigated, the disposition of the vein might have been found to resemble more closely that of the other animals.

DEVELOPMENT

DEVELOPMENT OF THE HEPATIC DUCTS, GALL-BLADDER &c IN THE PIG.

Although foreign to the research as originally planned, the development of the gall-bladder and its associated ducts arrested attention early in the course of the work. An examination of the literature revealed a want of information regarding the manner in which the duct-system of the liver becomes evolved during the embryonic history of the organ.

To my knowledge, Lewis (31) is the only writer who has given any detailed account of the characters of the embryonic hepatic ducts and gall-bladder of the pig. His account of them in a 12 mm. embryo is of considerable interest. He says that along the lower surface of the liver there is a tubular pouch whose diameter is greater than that of the intestine with which it is connected. The epithelium lining its interior differs from that forming the hepatic cylinders, but in some degree resembles that of the intestinal mucosa. This large pouch ends blindly at its ventral end, where it is separated from the liver by interposed mesoderm. Along the walls of the tube are knob-like buds of epithelium, more numerous in the parts nearer the intestine. Some of these buds are continuous with the epithelial cylinders of the hepatic tissue; some have no such connection; and others "are found as detached cysts in the liver". From the use the use of the word "cysts", one is led to assume that Lewis found them to contain cavities. The present writer, as will presently be shown, has also noticed isolated collections of cells which have apparently been detached from the epithelium of the tube described by Lewis as a pouch; but, in embryos about the size of that modelled by Lewis, it has never been noted that they enclose cavities.

Lewis goes on to say that "later all but one of "these hepatic ducts are obliterated, and the diver- "ticulum into which it empties has become in part the "cystic duct and in part the gall-bladder".

Brachet (55) had previously given a somewhat similar, though fuller, account of the development of the bile-ducts in the rabbit. The primitive diverticulum from the intestine, he says, becomes divided into two portions: the one, anterior, from which hepatic tissue is formed, and therefore the hepatic bud properly so-called; the other, posterior, the Anlage of the gall-bladder and cystic duct, and therefore meriting the name of cystic bud. The intermediate zone joining the anterior and posterior buds is also concerned in the formation of hepatic tissue.

In the youngest pig embryo (6 mm.) used in the research at present under discussion, there is a tube similar to that described and figured by Lewis, except that it is shorter and relatively more roomy. It is connected with the duodenum, from which it arises in

common

common with the ventral Anlage of the pancreas (Fig. 36). The more dorsal half is wider than that more distal, and from it spring five or six solid epithelial cords directly continuous with the hepatic cylinders (Fig. 36. b.). In addition, there are several knob-like buds (as mentioned by Lewis) which have no connection with the liver epithelium (Figs. 14 & 36. a.). The wide dorsal segment of the tube evidently corresponds to a combination of Brachet's hepatic bud and intermediate zone.

In the 8 mm. embryo the connection of the tube with the duodenum is relatively narrower, and the ventral Anlage of the pancreas arises from it a short distance from the intestine (Fig. 37). The whole tube, as in the younger embryo, is flattened from side to side, and one of its faces (the right) is applied to the liver. Three segments are now recognisable from the difference in their width. The proximal segment -forming rather more than one-third of the entire tube- is the widest, and extends slightly dorsal to the point of continuity with the duodenum. The middle segment is the narrowest part, and is succeeded by an expanded ventral segment -the shortest part of the tube in this embryo.

From the dorsal segment, and from this alone, proceed epithelial cords and buds similar in character and number to those of the 6 mm. embryo (Figs. 24 & 37). As has been said, the whole tube is flattened

from

from side to side, and the embryonic ducts arise from its anterior (cephalic) border and right surface, i.e. from those parts of the tube which are in contact with the liver. Lewis' figure (Plate III) indicates that they may also be connected with the left surface, but my models do not agree with those of Lewis on this point.

In a 15 mm. embryo a considerable change in the form of the tube is noticeable. Traced from its connection with the intestine, it first curves dorsalwards and to the right. The ventral Anlage of the pancreas has just lost its connection with the biliary system of ducts; but the point of former junction is indicated by a projection of the wall of the bile-duct (Fig. 38, (v.a.p.)).

The second part of the biliary tube is at first vertical in direction, and afterwards practically horizontal. That this corresponds to the wide dorsal segment of the former stage is demonstrated by the presence of epithelial cords and buds to which it gives origin (Fig. 32 & 38). The sudden bend which occurs in it may possibly be an individual peculiarity. since in the next older embryo it is practically absent.

The terminal part of the tube calls for no detailed description. It consists of a narrow cystic duct, and an expanded, but flattened, gall-bladder.

Isolated clumps of cells, evidently aborted ducts, are present in this and an older embryo.

In a

In a 25 mm. embryo the same features are present. There is the same initial curve in a dorsal direction, succeeded by the same stretch of tube from which bile-ducts and buds take origin. The most conspicuous ducts -two in number- originate close to the beginning of the cystic duct (Fig. 39). In embryos smaller than 25 mm., the cords of epithelium are apparently solid; but a lumen has appeared in the larger of them between the 15mm. and the 25mm. stages. The cystic duct and the gall-bladder are, on the whole, similar to those of the 15 mm. embryo, but the gall-bladder is no longer so markedly flattened but has a corrugated wall.

In connection with the development of the gall-bladder , it may be of moment to note that the embryos examined do not support a supposition expressed by Thomson (4) and arising out of his investigation of human foetal livers. He says that "the gall-bladder "appears to develope along the bottom of a fissure "which extends forwards to the anterior border (of the "liver), and which apparently is formed prior to the "appearance of the vesicle". So far as pig embryos go, there is no evidence that a groove is produced prior to the growth of the gall-bladder in a ventral direction. It appears rather that the presence of the vesicle determines the production of the groove.

From the present observations, combined with

those

those of Lewis on the pig and Brachet on the rabbit, it is clear that there are many more rudiments of hepatic ducts in the embryo than persist into adult life. Some of them evidently become abortive at so early a period that they cannot be properly described as ducts, i.e. they dwindle before a lumen makes its appearance within them. These remain for a time as small, solid epithelial masses continuous or not with the epithelium lining the derivatives of Brachet's hepatic bud and intermediate zone. That many of them finally disappear entirely is undoubted, for their number diminishes in older embryos. Whether they all cease to exist cannot be asserted from the material examined; but it seems just within the bounds of possibility that from them some of the mucous glands of the main bile-ducts may arise.

Other ducts evidently advance considerably in development and assume lumina before their connection with the primitive tube is severed. One is led to this conclusion by observing, in the 25 mm. embryo, a large and well-defined duct, with an obvious lumen, leaving the liver substance and proceeding for some distance towards the tube developed from Brachet's hepatic bud, but ending blindly in the mesoderm.

The persistence of duct-rudiments in a position other than that occupied by the normal vessels would give origin to aberrant ducts similar to those known as hepatoas hepato-cystic, so commonly met with opening directly into the gall-bladder of the ox (cf. Ellenberger and Baum (36)) and other animals, and occasionally recorded in the human subject.

The multiplicity of embryonic rudiments, moreover, explains the variability, which may be regarded as normal, in the number of ducts in some species of mammals. For example, in the cat, Johnson (37) has stated that in only 5% of the animals examined by him were the ducts typical; or, in other words, in only so small a percentage was every duct so arranged as to conform to the most usual condition of that particular duct. In 55 cats there was one duct in 7 animals; two ducts in 35; three ducts in 26; four ducts in 11; five ducts in 3; and six, seven, and nine ducts in single specimens. Although Johnson's figures, when reduced to a polygon of frequency, are not sufficient to satisfy the demands of the follower of modern biometrical methods, they are of interest to the anatomist as showing the great range of variability, and are of importance in connection with the embryology of the hepatic ducts.

The complex embryonic arrangement of the ducts is of further interest when compared with their disposition in the adult otter (Lutra vulgaris) as redescribed by Burne (38) in 1899. In the otter the cystic duct is double and connected with some twenty

ducts

ducts which intercommunicate and finally terminate in seven independent tubes opening into a short common duct by which the bile is conveyed into the intestine. It appears that the condition is normal, for it has been twice previously described; once by Lorenzini (39) in 1675, and again, in 1838, by Alessandrini (40).

A somewhat similar complexity occurring among the Reptilia (cf. Beddard on the Lacertilia (41)), the interpretation which naturally suggests itself is that the ducts of the mammalian embryo pass through a stage in their development reminiscent of the condition in reptilian ancestors. In the ordinary course of events, and in the great bulk of mammals, the ducts are reduced in number; but occasionally the more primitive plan is partly adhered to. This, obviously, is the merest hypothesis, and requires much more confirmation than is supplied by the facts at present known. The only assertion that can be made with safety is that instances of supernumerary ducts are examples of the persistence of embryonic tubes which normally fail to arrive at a high grade of development.

<u>SUMMARY</u>.

The chief points of moment in the foregoing account may be briefly summarised as follows:-

(1). The division of the liver as made by the human anatomist is convenient, but should not be held as resting upon an embryological or true morphological basis. The "umbilical fissure" in man, and in mammals in general, is not a true fissure. Its appearance is late, and it may become obliterated in the adult. Its occurrence depends upon the presence of the left umbilical vein. If the right umbilical vein were to persist as well two "fissures" would be produced, and the error of considering one of them as the dividing line of the liver would be manifest.

There is much to be said for Cantlie's (18) contention that a line drawn from the gall-bladder to the exit of the hepatic veins divides the liver into right and left halves.

(2). The mammalian liver consists essentially of three lobes -a central and two lateral. The usual division of the central lobe into two is correlated with the presence of an "umbilical fissure", and, therefore, is not fundamental. The caudate and Spigelian "lobes" are merely appendages or processes of the right lateral lobe. In order to indicate their true morphology, it would be better to name them caudate and omental or papillary processes.

In view

In view of developmental evidence, it appears reasonable to ask that the following modifications should be made in Flower's nomenclature:-

		FLOWER.
Central lobe.	Right lobule.	Right central lobe.
	Left lobule.	Left central lobe.
Right lateral lobe.	Main part.	Right lateral lobe.
	Processus caudatus.	Caudate lobe.
	Processus omentalis or papi-illaris.	Spigelian lobe.
Left lateral lobe.		Left lateral lobe.

(3). Not only do the three fundamental lobes make their appearance independently; they also develope in connection with different embryonic veins. The central lobe is produced about the umbilical veins. The right and left lateral lobes grow along the course of the right and left omphalo-mesenteric veins.

The right and left hepatic veins are primarily connected with the right and left lateral lobes respectively. The hepatic veins of the central lobe are of later development.

(4). Whatever may be the cause or causes of the presence of fissures in the mammalian liver, it cannot be admitted that, as yet, a satisfactory connection has been proved between facts and factors. The question is complicated by the possibility that

the

the fissures may be preceded by mesodermic septa which intervene between the lobes at an early period. The presence of such septa in the liver of the pig and hedgehog points to a new field of enquiry.

(5). There are many more rudiments of hepatic ducts than ever develope into the definitive ducts of the adult. The fate of those rudiments which become abortive still remains to be determined.

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Figs. 1, 2 and 3.

OUTLINES OF MODELS OF THE LIVER TO ILLUSTRATE THE DEVELOPMENT OF THE LOBES IN THE PIG.

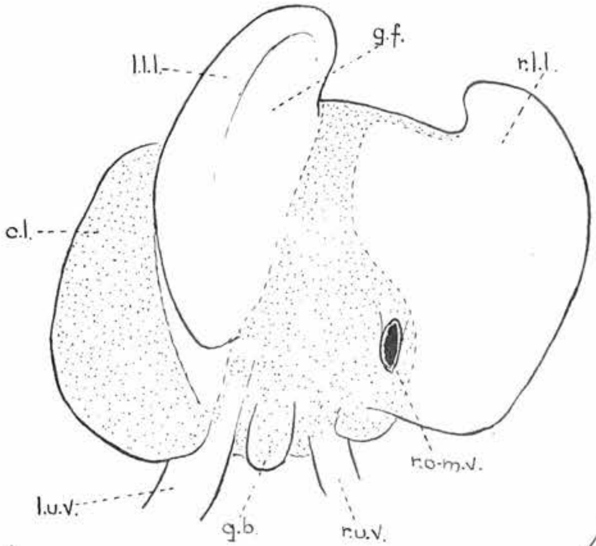
l.l.l = left lateral lobe; r.l.l = right lateral lobe; c.l. = central lobe; g.f. = fossa for stomach; l.u.v. = left umbilical vein; r.u.v. = right umbilical vein; r.o-m.v. = right omphalo-mesenteric vein; v.c. = vena cava; g.b. = gall-bladder; p.pap. = processus papillaris; caud. l. = caudate "lobe" (processus caudatus); p.pyr. = processus pyramidalis; paraum. lob. = paraumbilical lobule; q. lob. = "quadrate" lobule; p-c. lob. = praecaudate lobule; d-v. lob. = dextro-vesical lobule.

Fig. 1. Caudal surface of liver of 6 mm. (19 days') embryo. The large size of the right lateral lobe is obvious.

Fig. 2. Caudal surface of liver of 15 mm. (25 days') embryo. The fossa for the stomach is relatively smaller. Various processes and lobules have begun to form.

Fig. 3. Caudal surface of liver of 25 mm. (30 days') embryo. The fossa for the stomach is still smaller. a caval lobe is fairly well defined. The various processes and lobules are more prominent. A groove has appeared in the central lobe where the falciform ligament is attached. The large size of the central lobe can only be appreciated when the liver is viewed from the thoracic side.

In all the figures the dotted areas are not covered by peritoneum.



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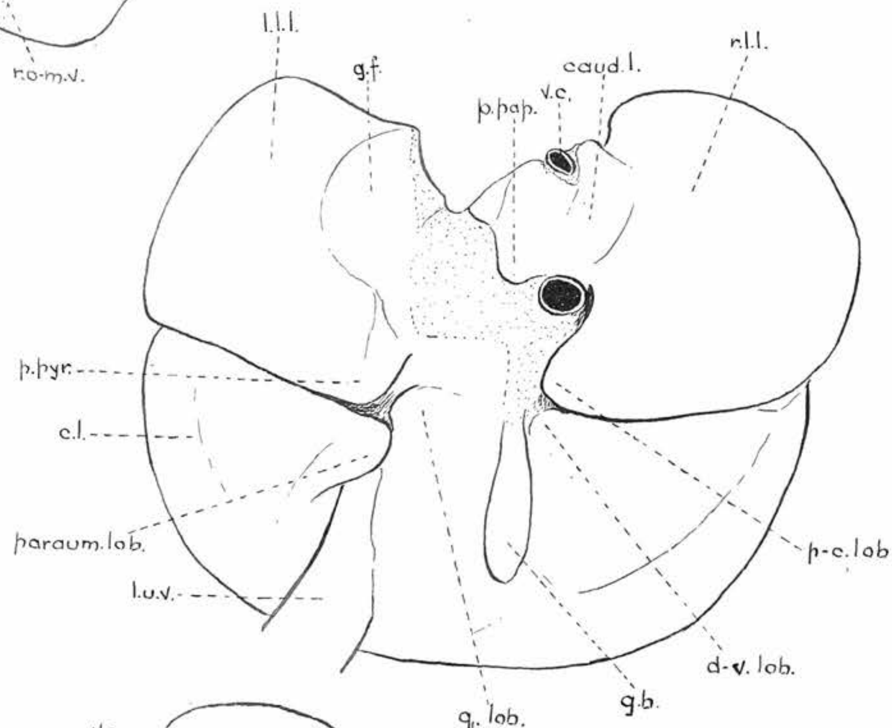

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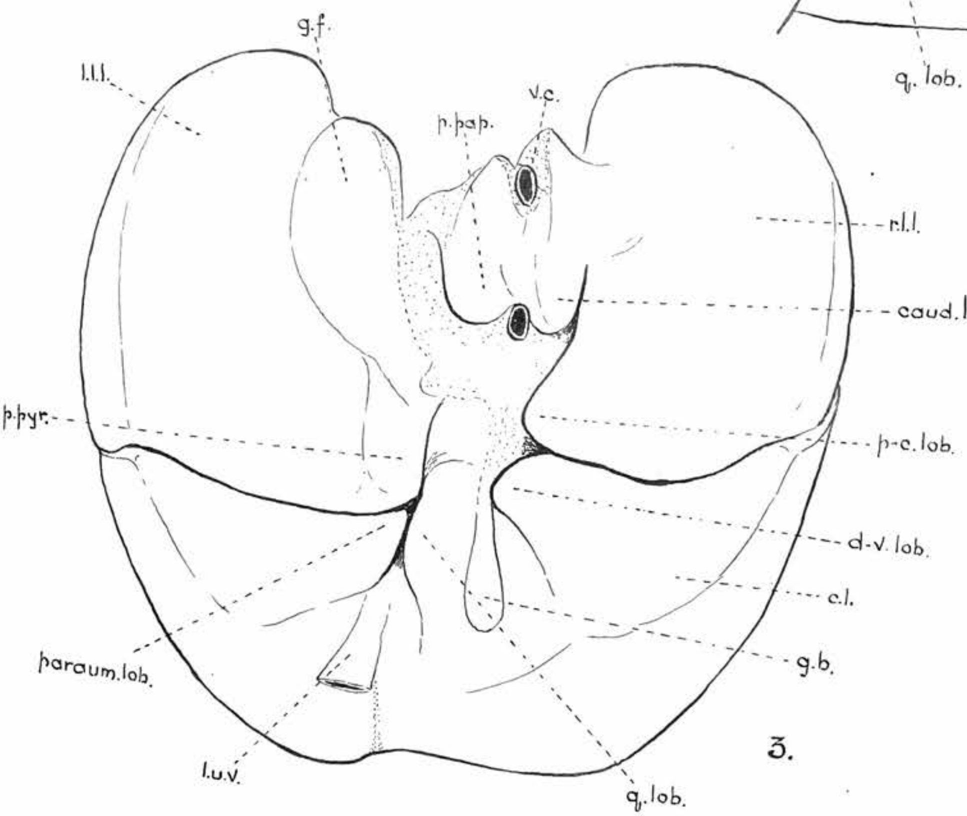

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3.

Figs. 4. 5. and 6.

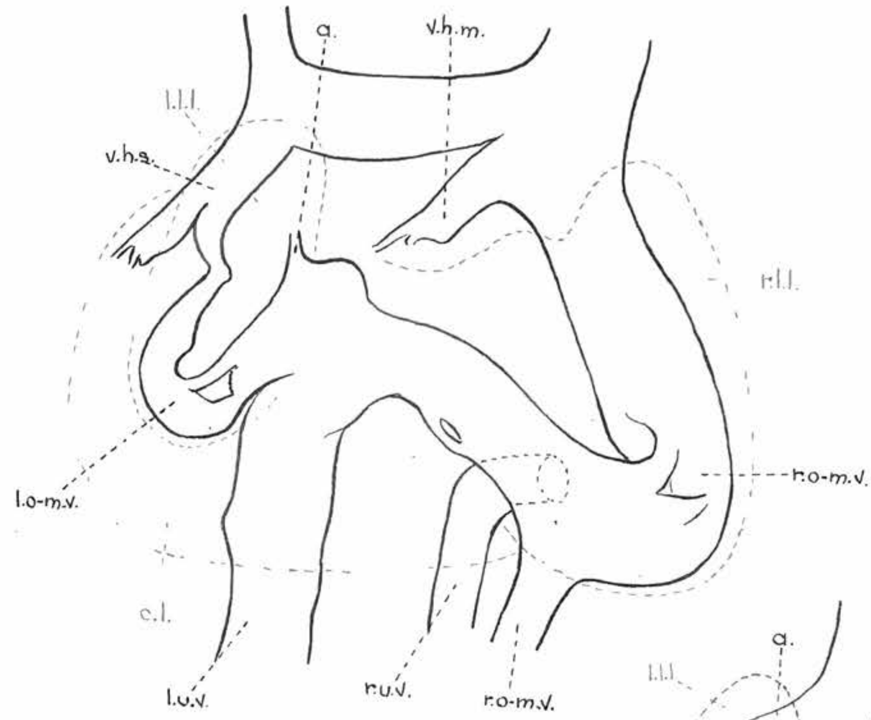
SEMIDIAGRAMMATIC OUTLINES OF MODELS OF HEPATIC VESSELS.

The lobes are outlined by dotted red lines. l.l.l. = left lateral lobe; r.l.l. = right lateral lobe; c.l. = central lobe; l.u.v. = left umbilical vein; r.u.v. = right umbilical vein; r.o-m.v. = right omphalo-mesenteric vein; l.o-m.v. = left omphalo-mesenteric vein; v.h.s. = vena hepatica sinistra; v.h.d. = vena hepatica dextra; v.h.m. = vena hepatica media; v.c. = vena cava; d.v. = ductus venosus; r.arc. = ramus arcuatus; l.a. = left arborisation from the recessus umbilicalis.

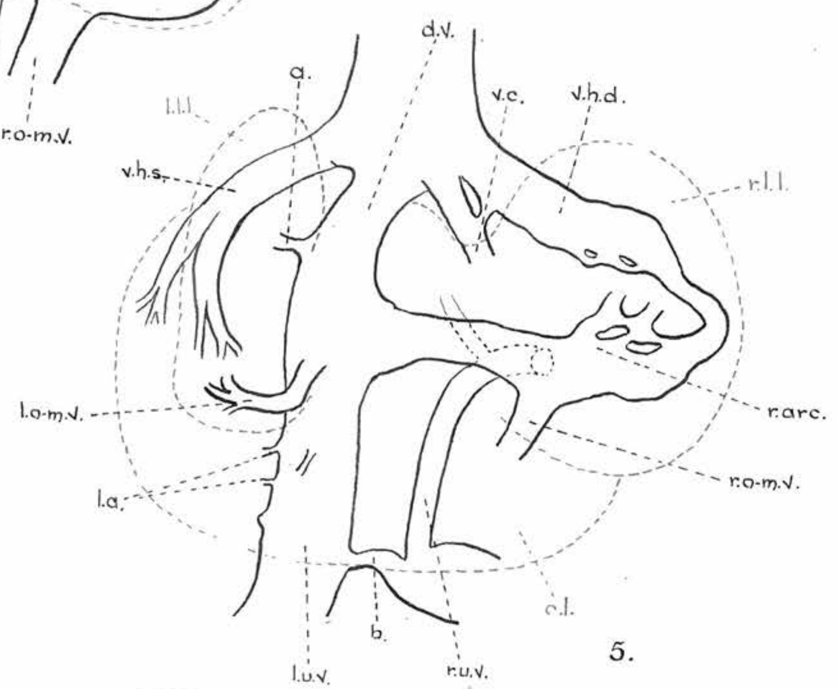
Fig. 4. Vessels of liver of 6 mm. (19 days') pig embryo. There is no ductus venosus. a. = a small vein which ultimately becomes the ramus angularis.

Fig. 5. Vessels of liver of 8 mm. (22 days') pig embryo as viewed from the caudal aspect. The ductus venosus is present. a. = the same as in fig. 4. o. = connection between the two umbilical veins. The left arborisation (l.a.) from the recessus umbilicalis (Rex) has begun to form.

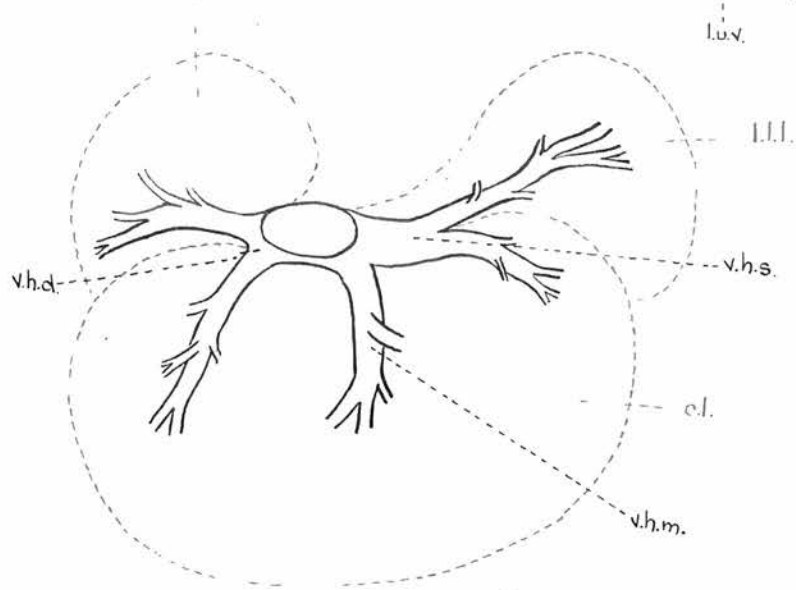
Fig. 6. Hepatic veins of 8 mm. (22 days') pig embryo as viewed from the thoracic aspect. The right and left veins are formed by two tributaries each; a dorsal from the lateral lobe, and a ventral from the central lobe. The middle hepatic vein opens close to the termination of the left vein.


a.
v.h.m.
l.l.l.
v.h.s.
r.l.l.
l.o-m.v.
r.o-m.v.
c.l.
l.u.v.
r.u.v.
r.o-m.v.

4.


d.v.
a.
l.l.l.
v.c.
v.h.d.
v.h.s.
r.l.l.
r.arc.
l.o-m.v.
r.o-m.v.
l.a.
c.l.
b.
l.u.v.
r.u.v.

5.


r.l.l.
l.l.l.
v.h.d.
v.h.s.
c.l.
v.h.m.

6.

Figs. 7, 8 and 9.

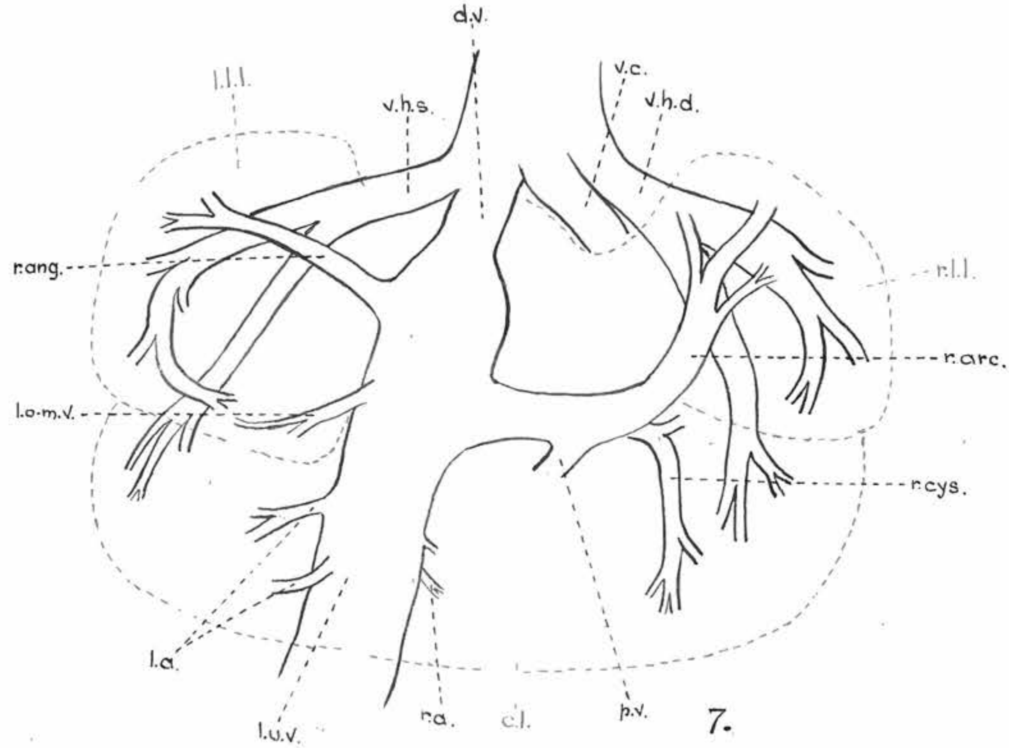
SEMIDIAGRAMMATIC OUTLINES OF MODELS OF HEPATIC VESSELS.

The lobes are outlined by dotted red lines. l.l.l. = left lateral lobe; r.l.l. = right lateral lobe; c.l. = central lobe; l.u.v. = left umbilical vein; r.u.v. = right umbilical vein; p.v. = portal vein; l.o-m.v. = left omphalo-mesenteric vein; v.h.s. = vena hepatica sinistra; v.h.d. = vena hepatica dextra; v.h.m. = vena hepatica media; v.c. = vena cava; d.v. = ductus venosus; r.arc. = ramus arcuatus; l.a. = left arborisation from the recessus umbilicalis; r.ang. = ramus angularis; r.cys. = ramus cysticus; r.a. = right arborisation from the recessus umbilicalis.

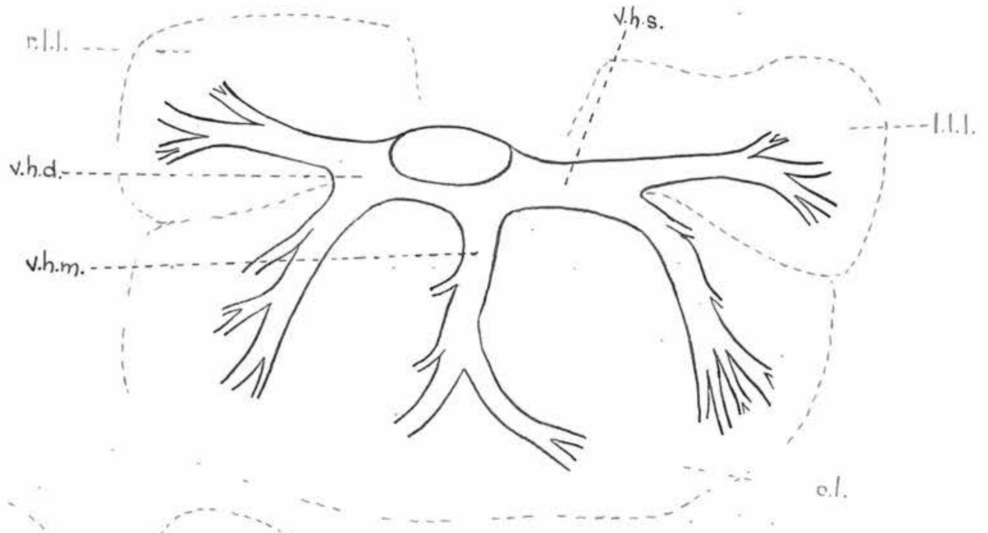
Fig. 7. Vessels of liver of 15 mm. (25 days') pig embryo as viewed from the caudal aspect. The vessel marked **a** in the previous figures has become a ramus angularis. The intra-hepatic part of the right umbilical vein is not present, unless the ramus cysticus has developed from it.

Fig. 8. Hepatic veins of 15 mm. (25 days') pig embryo as viewed from the thoracic aspect. The middle hepatic vein now arises as two tributaries -right and left.

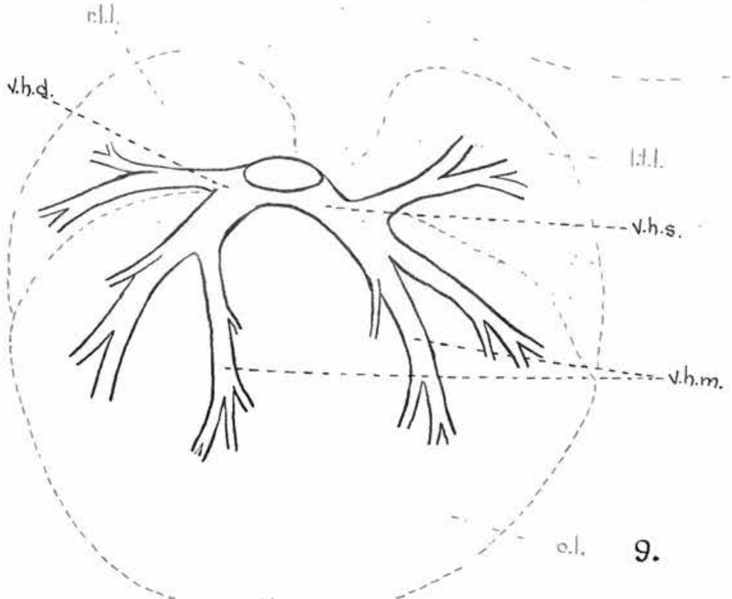
Fig. 9. Hepatic veins of 13 mm. mole embryo as viewed from the thoracic aspect. The right and left veins resemble the corresponding vessels of the pig; but the middle vein is represented by two vessels communicating with the right and left veins.


d.v.
v.c.
l.l.l.
v.h.s.
v.h.d.
r.l.l.
r.ang.
r.arc.
l.o.m.v.
r.cys.
l.a.
l.u.v.
r.a.
c.l.
p.v.

7.


v.h.s.
r.l.l.
l.l.l.
v.h.d.
v.h.m.
c.l.

8.


r.l.l.
v.h.d.
l.l.l.
v.h.s.
v.h.m.
c.l.

9.

Figs 10, 11, 12, 13, 14 and 15.

CAMERA LUCIDA DRAWINGS OF SECTIONS OF 6 mm. (19 DAYS') PIG EMBRYO.

l.l.l. = left lateral lobe; r.l.l.= right lateral lobe; c.l. = central lobe; l.u.v. = left umbilical vein; r.u.v. = right umbilical vein; l.o-m.v. = left omphalo-mesenteric vein; r.o-m.v. = right omphalo-mesenteric vein; st. = stomach; d. = duodenum; g.b. = gall-bladder; d.a.p. = dorsal Anlage of pancreas; v.a.p. = ventral Anlage of pancreas.

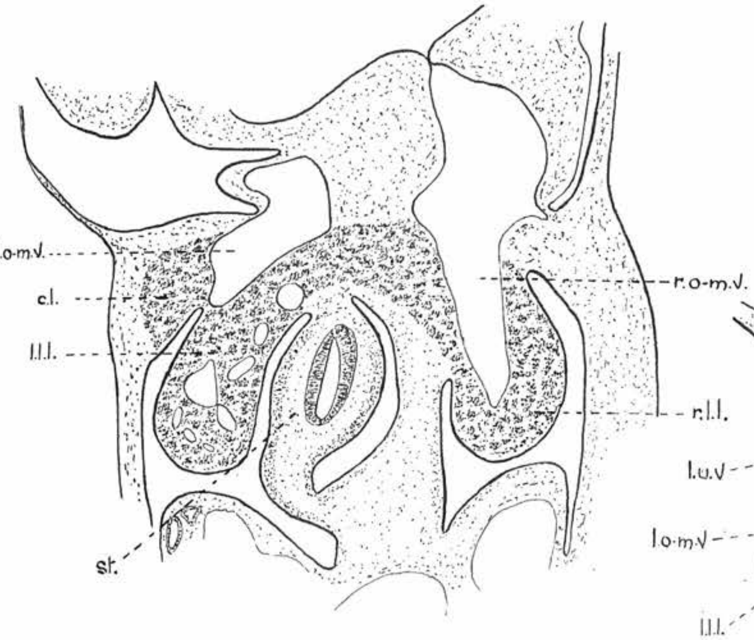
Figs. 10, 11, 12 and 13. Sections of liver &c beginning in the dorsal part.

Fig. 12. shows the connection between the right omphalo-mesenteric and right umbilical veins.

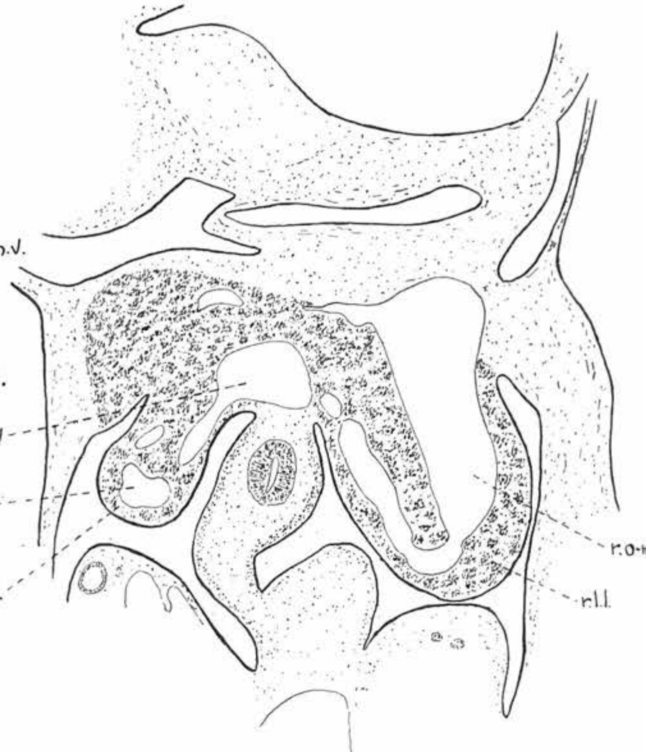
Fig. 13 illustrates the symmetrical disposition of the two umbilical veins on each side of the gall-bladder.

Fig. 15 shows how nearly the two umbilical veins approach each other. There is, however, no intercommunication.

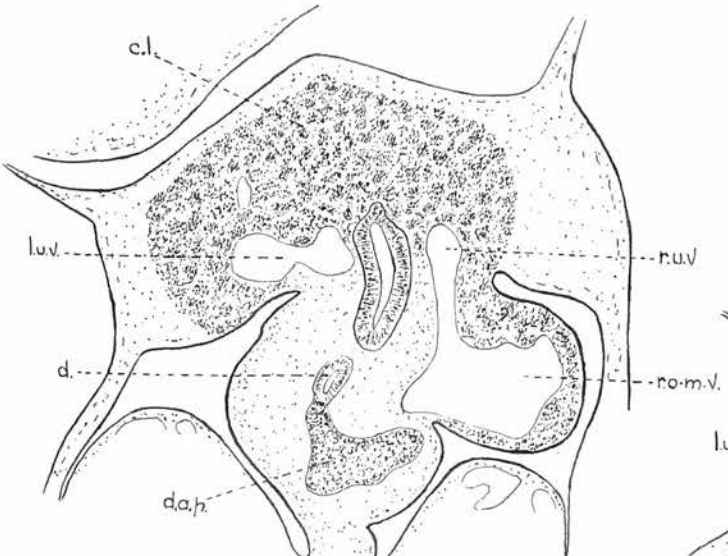
Fig. 14 illustrates the epithelial outgrowths from the hepatic bud. Those at the top of the figure are connected with the hepatic cylinders. a is merely a bud, and has no connection with the liver.


l.o-m.v.
c.l.
l.l.l.
st.
r.o-m.v.
r.l.l.

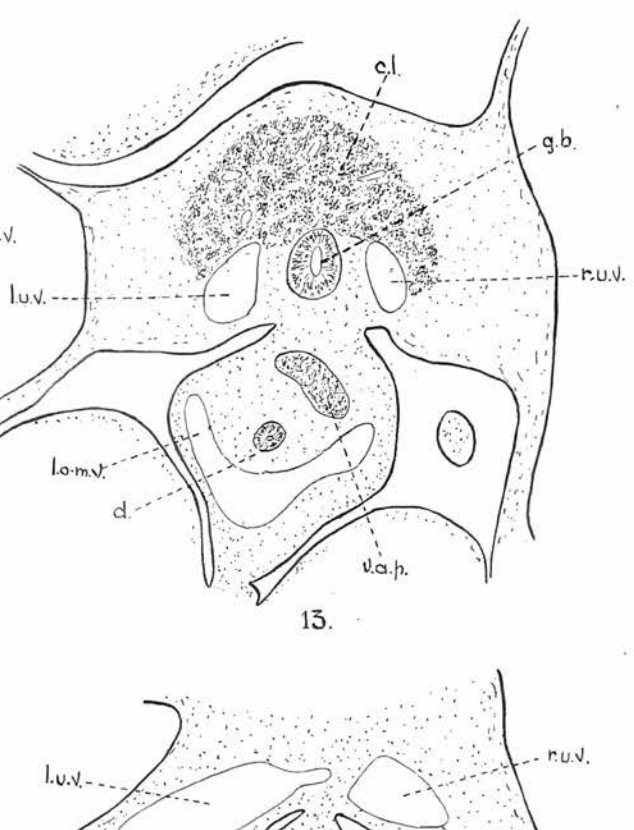
10.


l.u.v
l.o-m.v
l.l.l.
r.l.l.

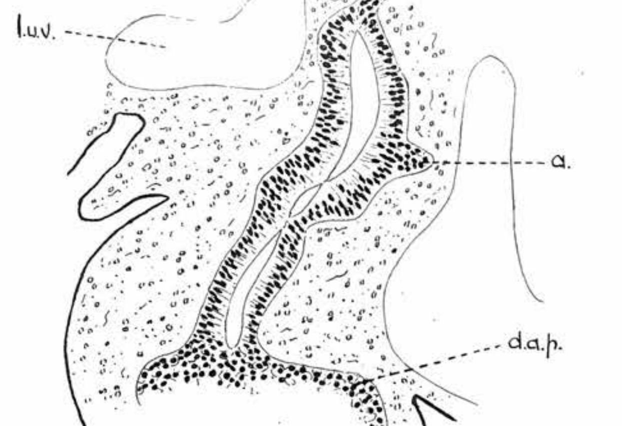
11.


c.l.
l.u.v.
d.
d.a.p.
r.u.v
r.o-m.v.

12.


c.l.
g.b.
l.u.v.
r.u.v.
l.o-m.v.
d.
v.a.p.

13.


l.u.v.
a.
d.a.p.


l.u.v.
r.u.v.
l.o-m.v.

Figs. 16, 17, 18, 19, 20 and 21.

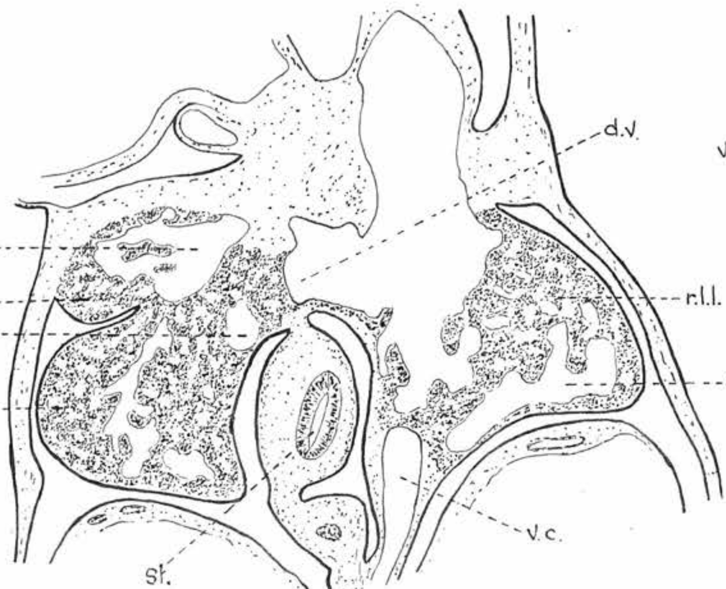
CAMERA LUCIDA DRAWINGS OF SECTIONS OF 8 mm. (22 DAYS') PIG EMBRYO.

l.l.l = left lateral lobe; r.l.l. = right lateral lobe; c.l. = central lobe; l.o-m.v. = left omphalo-mesenteric vein; r.o-m.v. = right omphalo-mesenteric vein; l.u.v. = left umbilical vein; r.u.v. = right umbilical vein; v.h.s. = vena hepatica sinistra; v.h.m. = vena hepatica media; d.v. = ductus venosus; v.c. = vena cava; st. = stomach; d. = duodenum; g.b. = gall-bladder; d.a.p = dorsal Anlage of pancreas; a. = the small vein which ultimately becomes the ramus angularis.

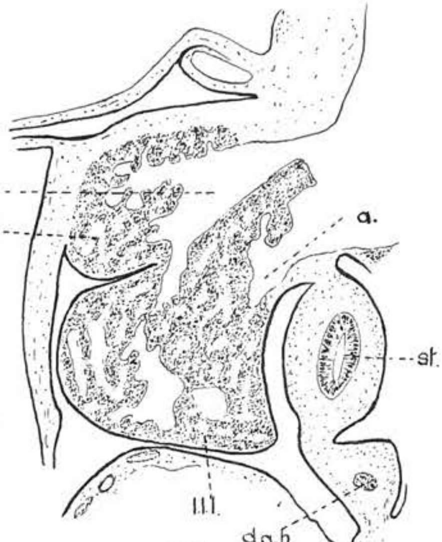
Fig. 18 shows that the right omphalo-mesenteric vein is still uninterrupted.

Fig. 19 indicates the position of the middle hepatic vein with regard to the left umbilical vein.

Figs. 20 and 21 should be compared with fig 13, as they show the relative positions of the two umbilical veins. Fig. 20 illustrates a section more ventral than that figured in fig.21.

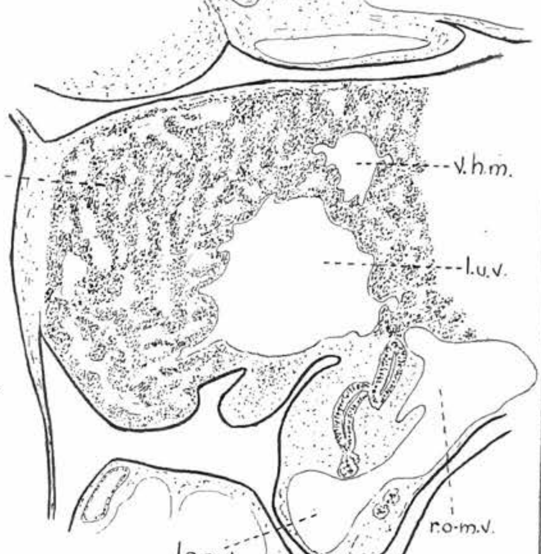


16.



17.

18.



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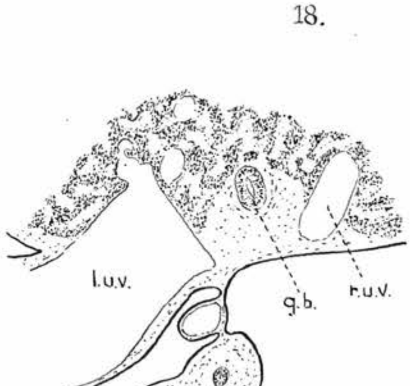
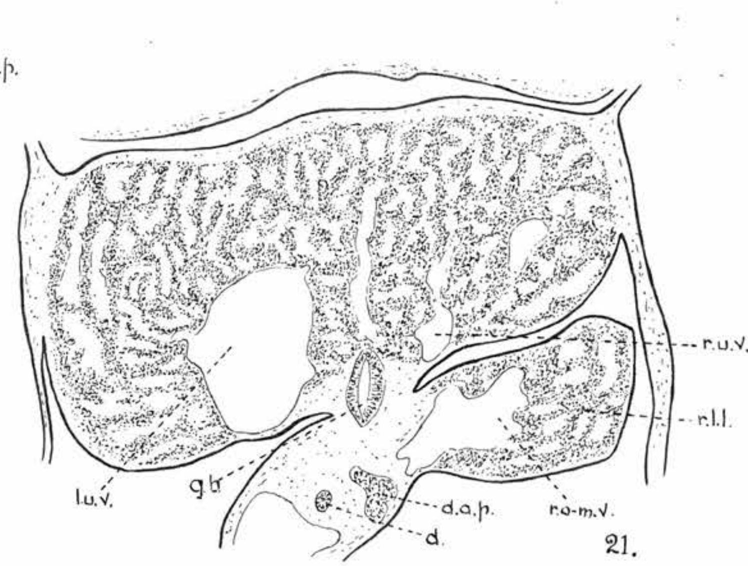


20.



21.

Figs. 22, 23 and 24.

CAMERA LUCIDA DRAWINGS OF SECTIONS OF 8 mm. (22 DAYS') PIG EMBRYO.

c.l. = central lobe; l.u.v. = left umbilical vein; r.u.v. = right umbilical vein; g.b. = gall-bladder; d. = duodenum; int. = intestine.

Fig. 22 shows the intercommunication between the two umbilical veins.

Fig. 23 illustrates a section just ventral to the communication shown in previous figure. Note the difference in size of the right umbilical vein before (Fig. 23) and after (Fig. 22) the communication.

Fig. 24. The embryonic hepatic ducts. a is not connected with liver epithelium; b and c are so connected. Compare with fig. 14.

Figs. 25, 26, 27, 28 and 29.

CAMERA LUCIDA DRAWINGS OF SECTIONS OF 15 mm. (25 DAYS') PIG EMBRYO.

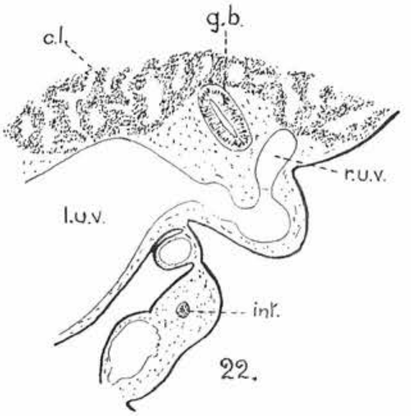
l.l.l. = left lateral lobe; r.l.l. = right lateral lobe; c.l. = central lobe; l.u.v. = left umbilical vein; d.v. = ductus venosus; l.o-m.v. = left omphalo-mesenteric vein; p.v. = portal vein; r.ang. = ramus angularis; r.arc. = ramus arcuatus; r.cys. = ramus cysticus; v.h.s. = vena hepatica sinistra (v.h.s.1. = dorsal tributary; v.h.s.2. = ventral tributary); v.h.d. = vena hepatica dextra (v.h.d.1. = dorsal tributary; v.h.d.2. = ventral tribuiary); v.h.m. = vena hepatica media; st. = stomach; d. = duodenum; c.d. = cystic duct.

Fig. 25 is most dorsal.

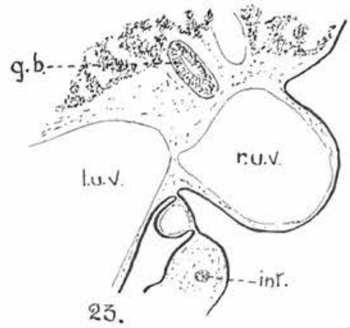
Figs. 28 and 29 show that the left omphalo-mesenteric vein is relatively smaller.

Fig. 29. Compare position of ramus cysticus with that of the right umbilical vein in fig. 21.

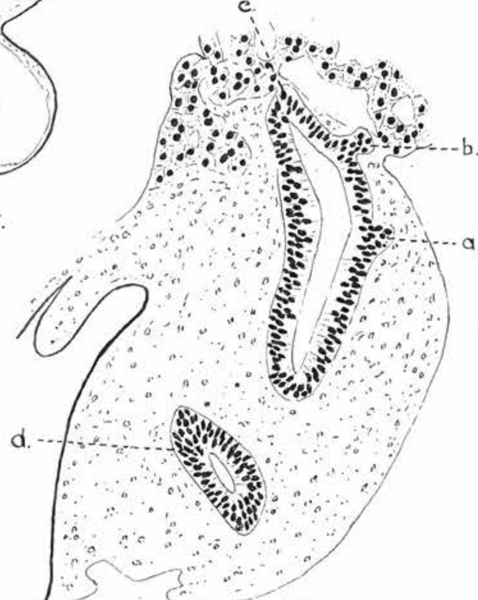
Figs. 26, 28 and 29. Note the presence of mesodermic septa between the central and right lateral lobes.



22.



23.



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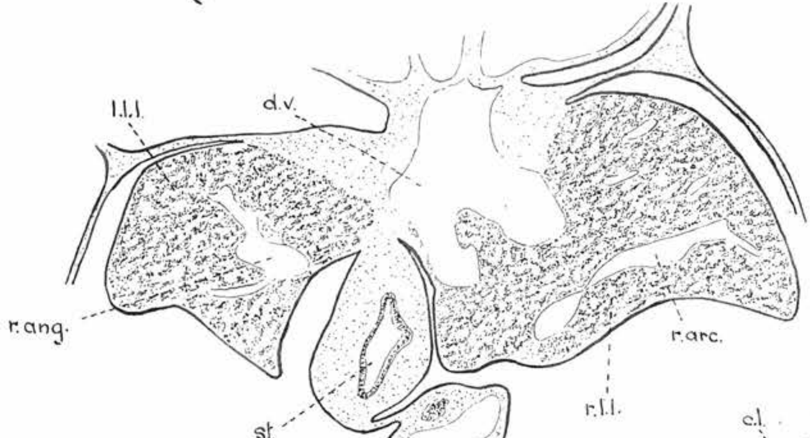
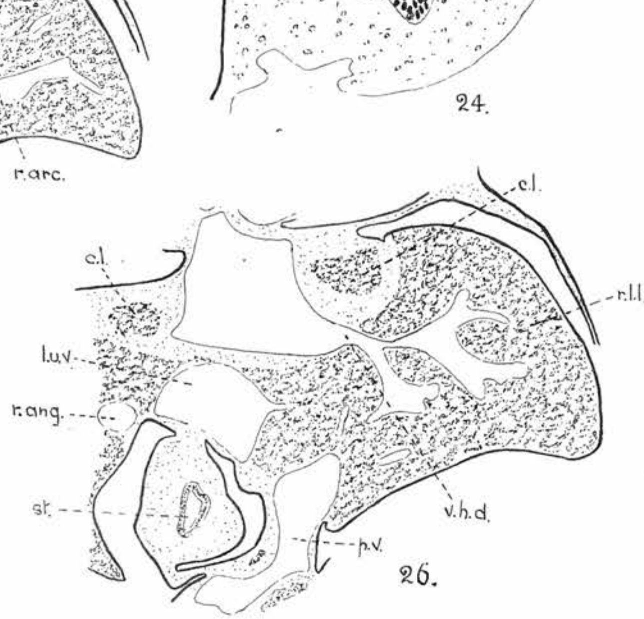


25.



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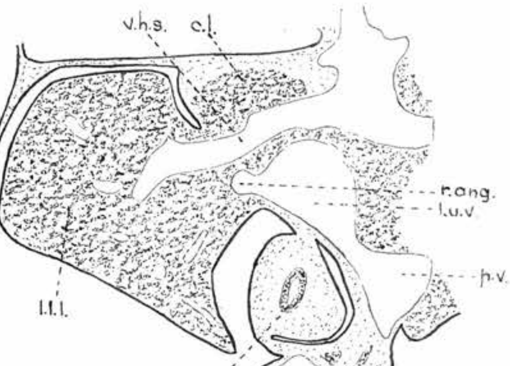
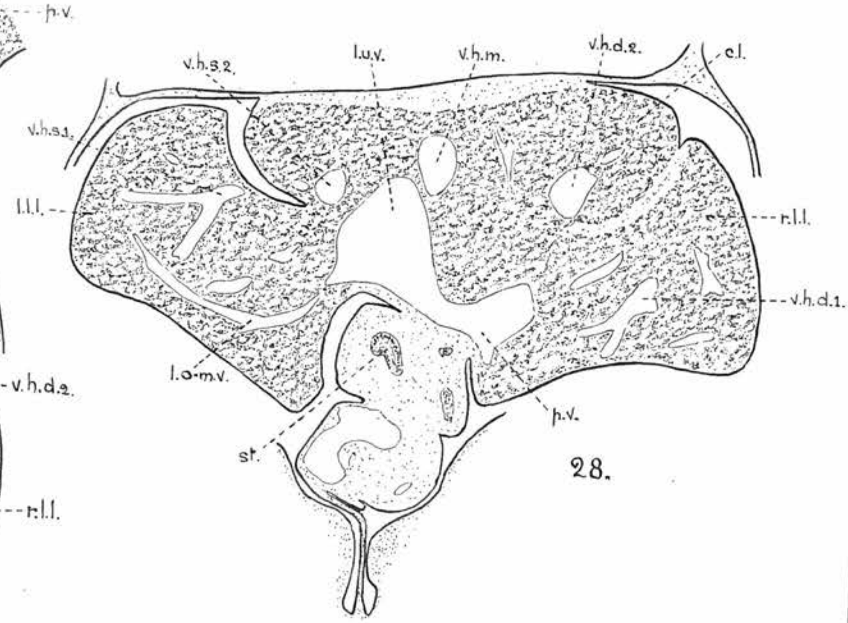
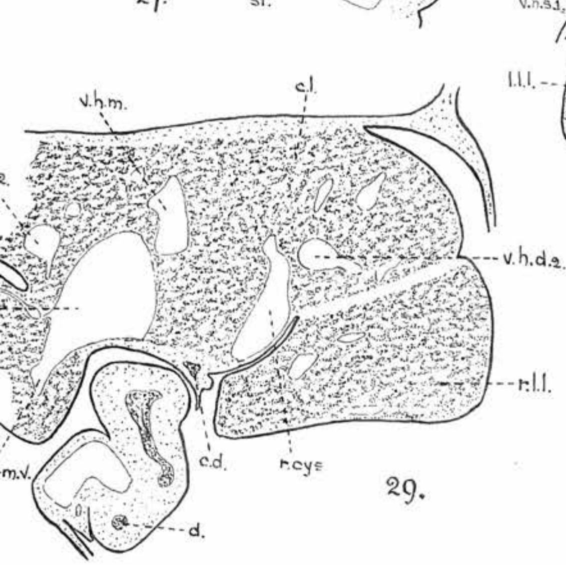


27.



28.



29.

Figs. 30, 31 and 32.

CAMERA LUCIDA DRAWINGS OF SECTIONS OF 15 mm. (25 DAYS') PIG EMBRYO.

c.l. = central lobe; l.u.v. = left umbilical vein; r.cys. = ramus cysticus; v.h.s.2. = ventral tributary of left hepatic vein; v.h.d.2. = ventral tributary of right hepatic vein; v.h.m.1. & v.h.m.2. = right and left tributaries of middle hepatic vein; l.a. = left arborisation from recessus umbilicalis; c.d. = cystic duct.

Fig. 30 shows the two tributaries of the middle hepatic vein just about to join. The position of the ramus cysticus should be compared with figs. 13, 20 and 21.

Fig. 31. a = the remains of the communication between the two umbilical veins.

Fig. 32. The hepatic ducts. a ends as a bud (as in figs. 14 and 24); but it is not necessarily the same bud which is figured in the three drawings. b is connected with liver epithelium.

Fig. 33.

CAMERA LUCIDA DRAWING OF SECTION OF 13 mm. MOLE EMBRYO

The same lettering as before, and in addition:- l.l.l. = left lateral lobe; r.l.l. = right lateral lobe; caud. l. = caudate "lobe"; p.pap. = processus papillaris; st. = stomach; r.ang. = ramus angularis; r.arc. = ramus arcuatus; r.cys. = ramus cysticus; r.desc. = ramus descendens.

The figure shows that the rami cysticus, arcuatus and descendens arise about the same point. It also shows the widely separated vessels which represent the middle hepatic vein.

Fig. 34.

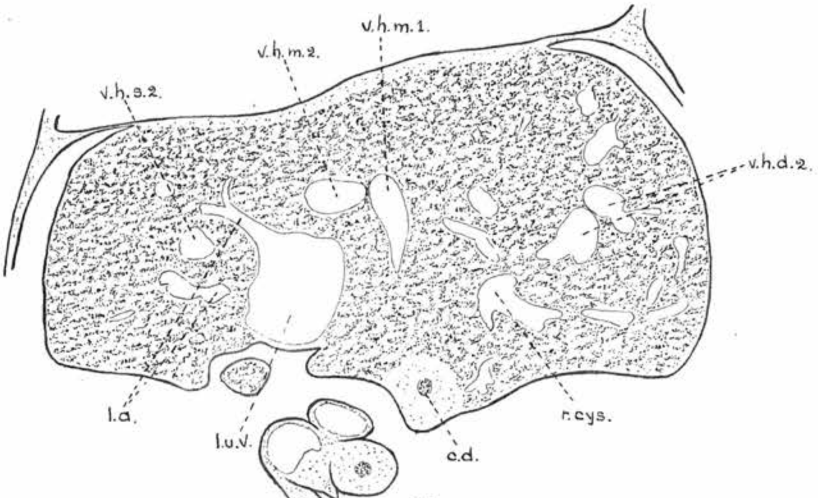
CAMERA LUCIDA DRAWING OF SECTION OF 11 mm. HEDGEHOG EMBRYO.

Lettering as before. r.oment. = ramus omentalis.

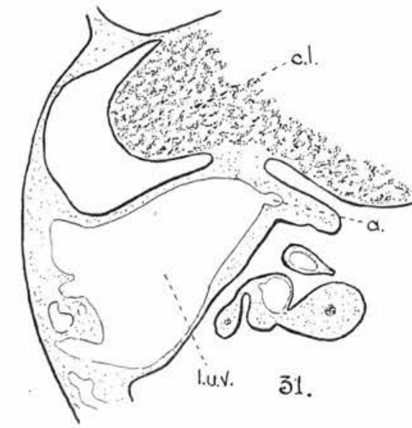
Fig. 35.

CAMERA LUCIDA DRAWING OF SECTION OF 5 mm. RAT EMBRYO.

Lettering as before. The right umbilical vein is not connected with the liver.



30.



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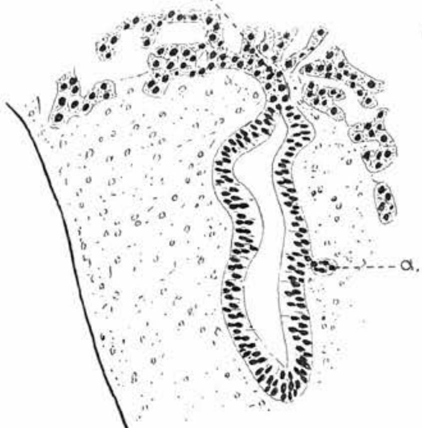
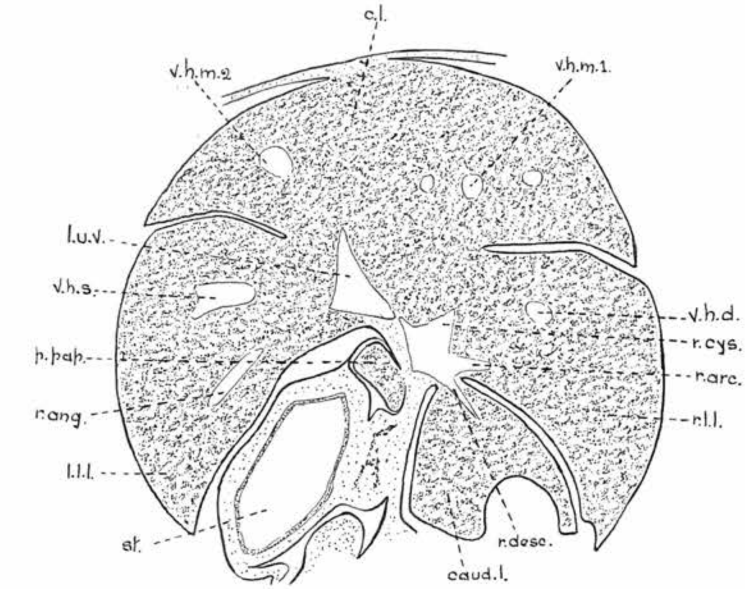


32.



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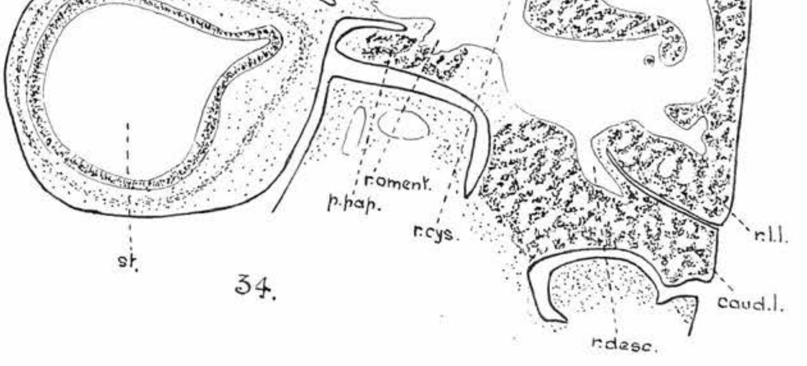

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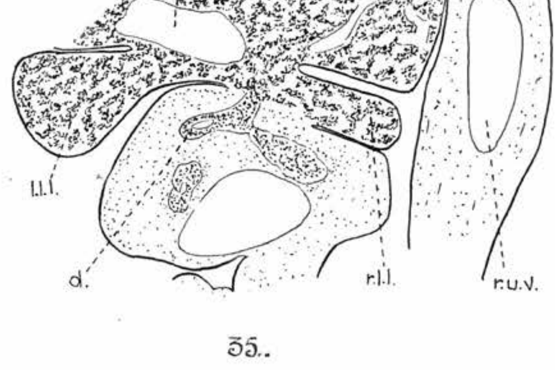


35.

Figs. 36, 37, 38 and 39.

OUTLINES OF MODELS ILLUSTRATING THE DEVELOPMENT OF THE GALL-BLADDER, HEPATIC DUCTS &c OF THE PIG.

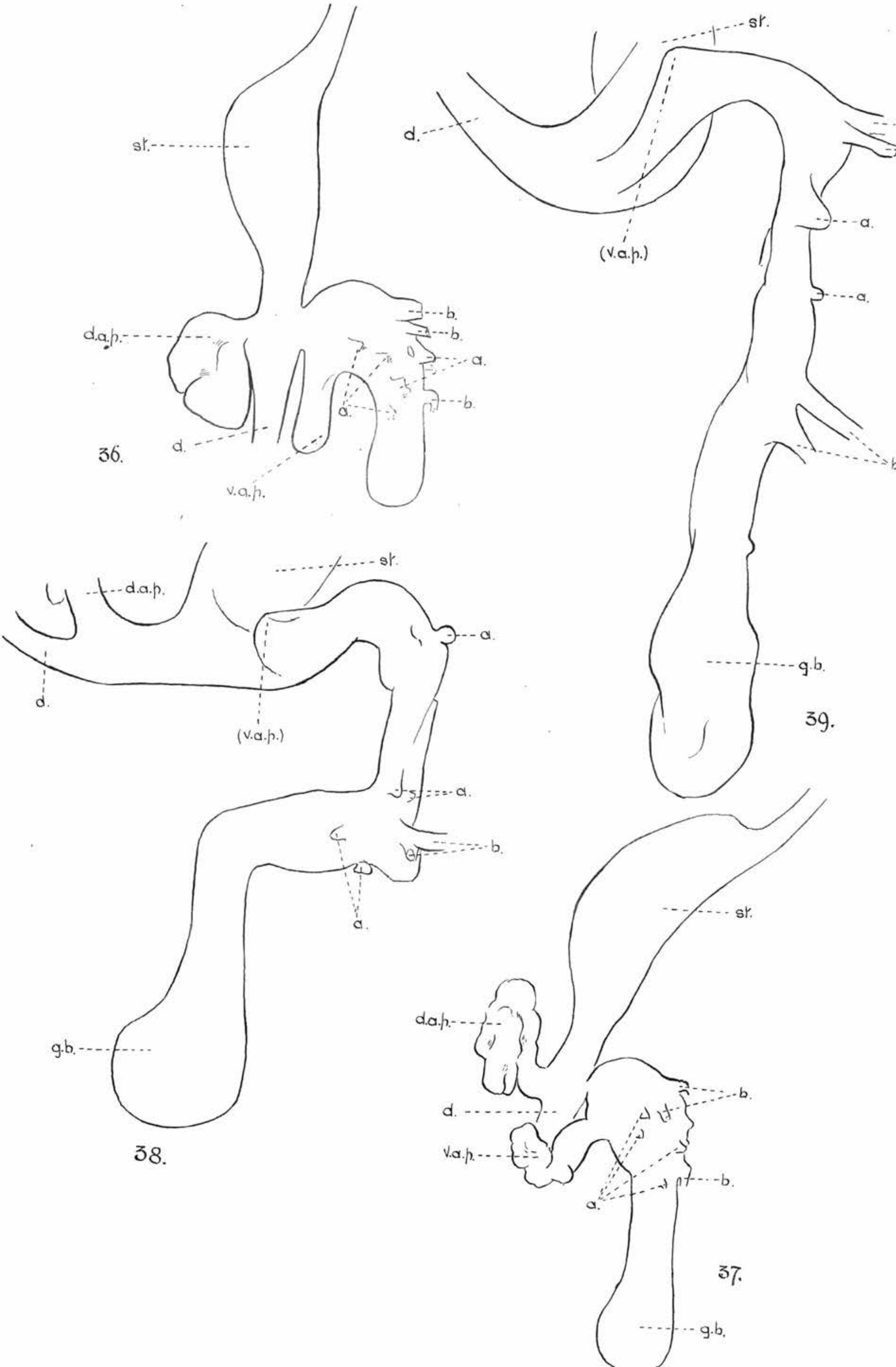
st. = stomach; d. = duodenum; d.a.p. = dorsal Anlage of the pancreas; v.a.p. = ventral Anlage of the pancreas; g.b. = gall-bladder; a. = buds of epithelium with no connection with hepatic cylinders; b. = epithelial cords connected with the liver.

Fig. 36. 6 mm. (19 days') embryo.

Fig. 37. 8 mm. (22 days') embryo.

Fig. 38. 15 mm. (25 days') embryo. (v.a.p.) indicates the position of former continuity of ventral Anlage of the pancreas.

Fig. 39. 25 mm. (30 days') embryo. (v.a.p.) as in fig. 38.


st.
d.a.p.
b.
b.
a.
b.
a.
d.
v.a.p.
st.
d.
b.
a.
a.
a.
(v.a.p.)
b.
g.b.
st.
d.a.p.
a.
d.
(v.a.p.)
a.
b.
a.
g.b.
st.
d.a.p.
b.
d.
v.a.p.
b.
a.
g.b.

36.

37.

38.

39.